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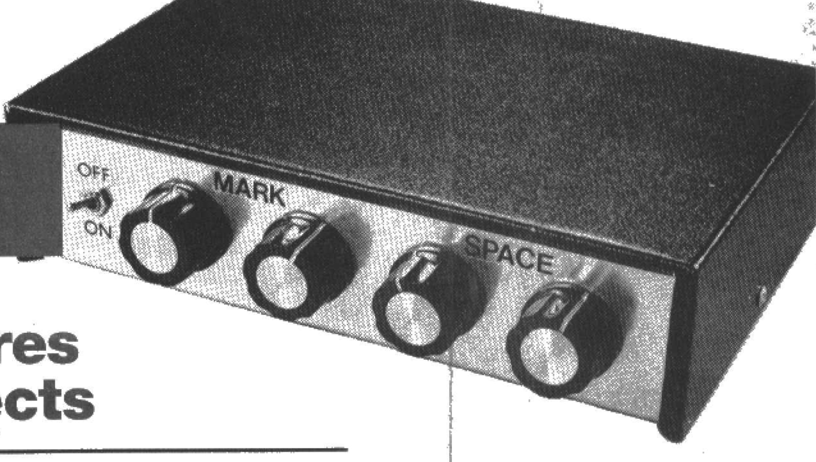

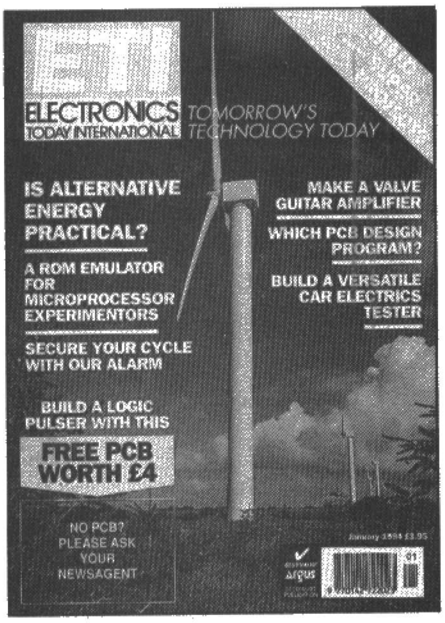
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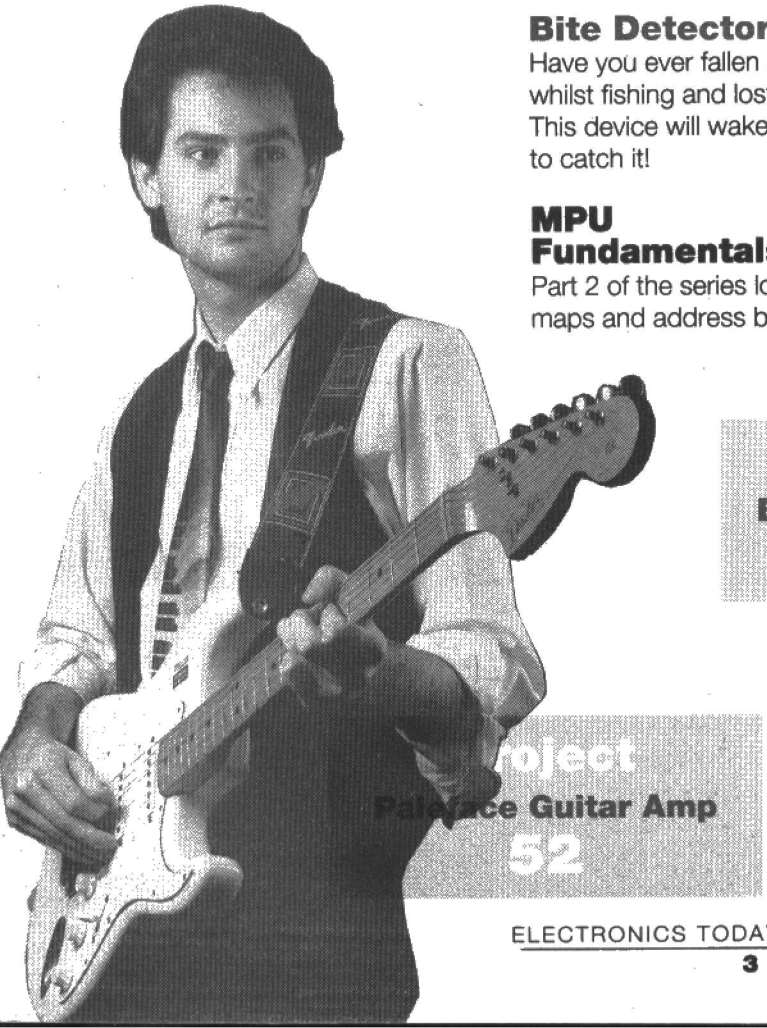
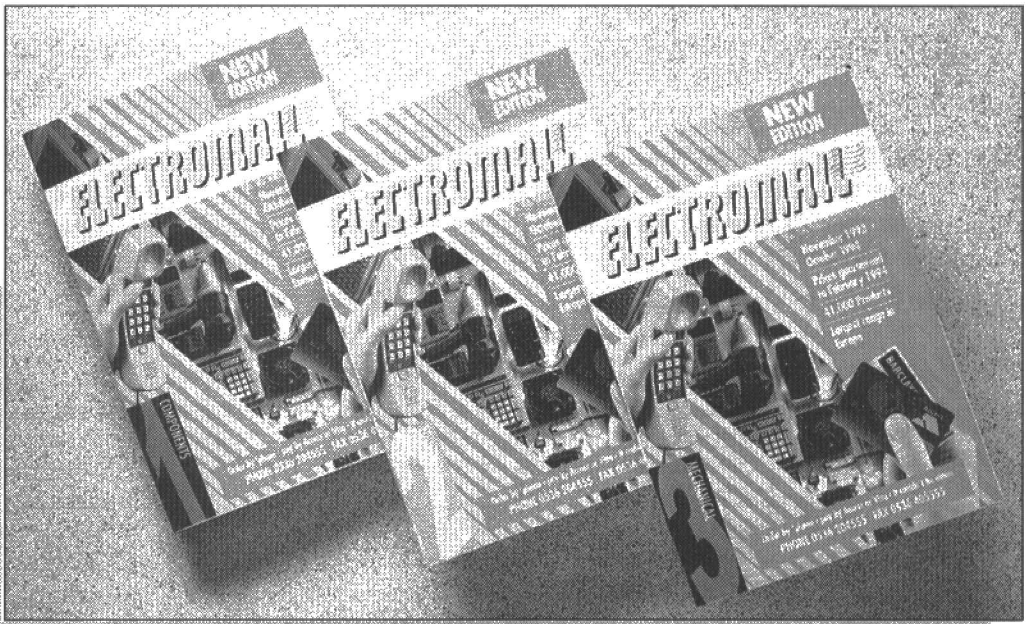


ETI NEWS

Low cost catalogue from Electromail



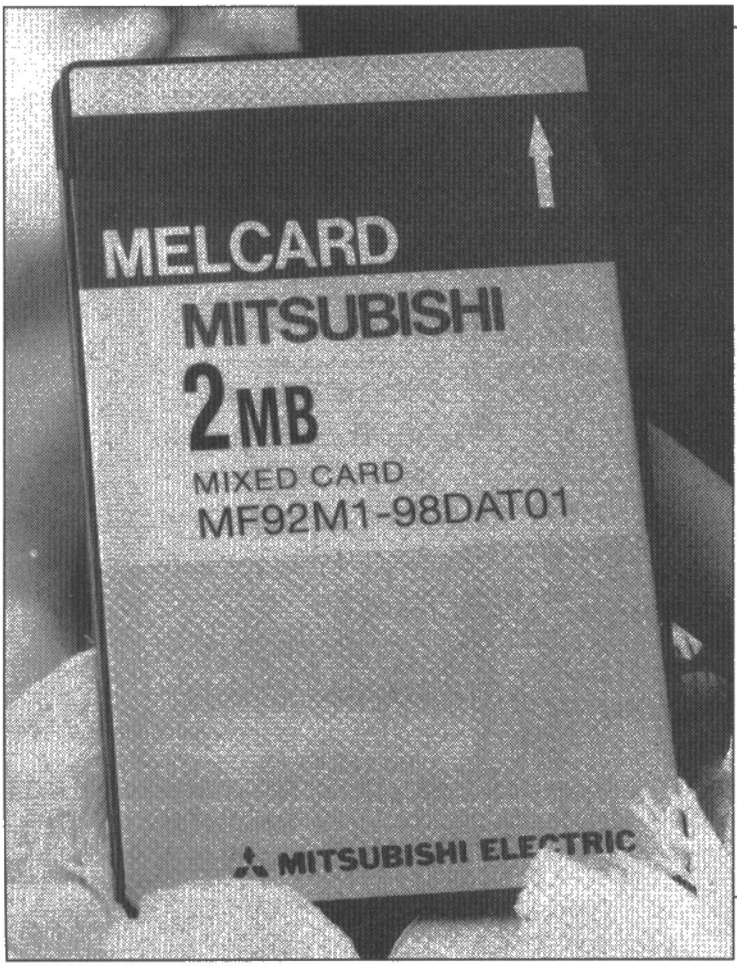
Until 31st December, Electromail, the mail order arm of RS Components, is offering its full colour catalogue at a reduced price of just £2.95. The three part, 2000 page, catalogue is usually priced at £6.50 and gives customers immediate access to an extensive range of over 41,000 RS electronic, electrical and mechanical parts and tools.

Electromail can be contacted on 0536 204555.

Oxford switches to electric transport

The city of Oxford now has an electric bus service, part of the city's move towards creating a better environment. Four buses powered by lead acid batteries are now running a regular service on a 4km circuit in the city. Each bus carries up to 18 people and has a top speed of 64km per hour.

The £125,000 buses are being provided by Southern Electricity and subsidised by the council. They have been designed by International Automotive Design of Worthing in Sussex and should help to reduce the level of nitrogen dioxide pollution in the city centre.



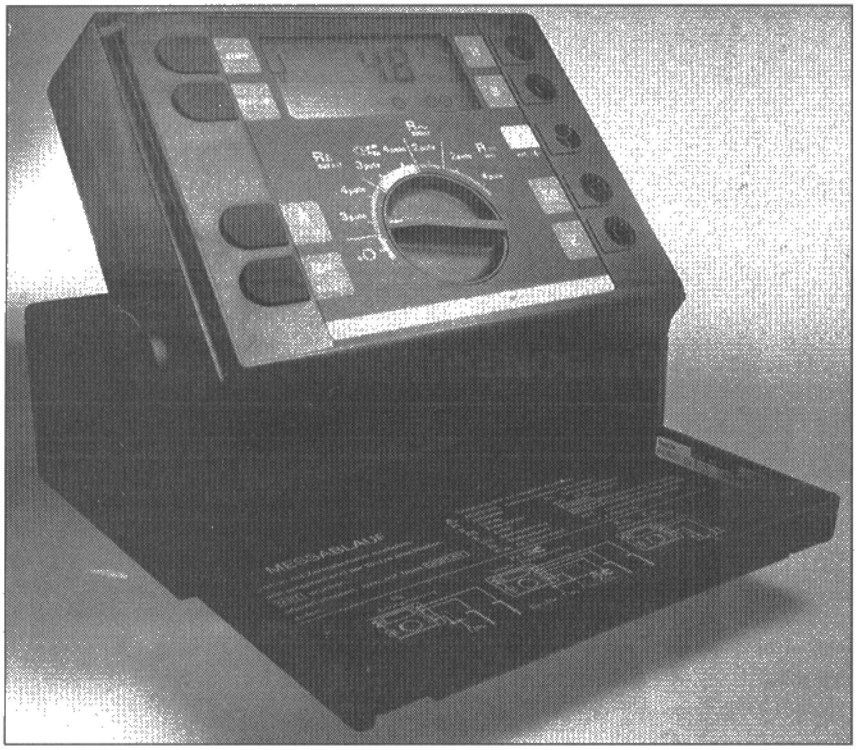
Mixed technology memory cards from Mitsubishi

Two new series of mixed technology 68 pin PCMCIA version 2/JEIDA version 4 standard memory cards have been launched by Mitsubishi. The two series are firstly a mix of SRAM and Flash and, secondly, a mix of OTPROM and EEPROM.

The SRAM and Flash mixed cards are available in mixes up to 2Mb of total memory. As such they provide ideal solutions to the data and program storage requirements of very small computer systems. The 200ns fast access cards are buffer interfaced and incorporate attribute memory. Programming and data erasing is by software control under the Flash memory and a life of up to 10,000 Flash memory programming cycles can be achieved.

The OTPROM and EEPROM versions are available with 1 or 2Mb of OTPROM and 64 or 256Kb of EEPROM, plus decoder ICs. Applications for these cards include multi-function terminals, instrumentation and measurement. The cards feature an 8 bit data length and an access time of 250ns.

For more information contact Mitsubishi on 0707 276100.



Safe earth testing

We all rely on the fact that electrical systems are properly earthed to guarantee their safety, but is the earth wire properly earthed? A new device from Manchester based Alpha Electronics allows you to test individual earth resistance in multiple earthed systems. This can be carried out safely without any need for disconnection. The system is ideal for testing power pylons, grounding grids and lighting protection systems.

The Unilap GEO-X also offers low resistance and two pole measurement with an AC resolution of 0.001 ohms. Automatic frequency control has been incorporated to ensure measurement validity. Microprocessor controlled measurements are presented on a large, high contrast, LCD and may also be downloaded to a PC or printer.

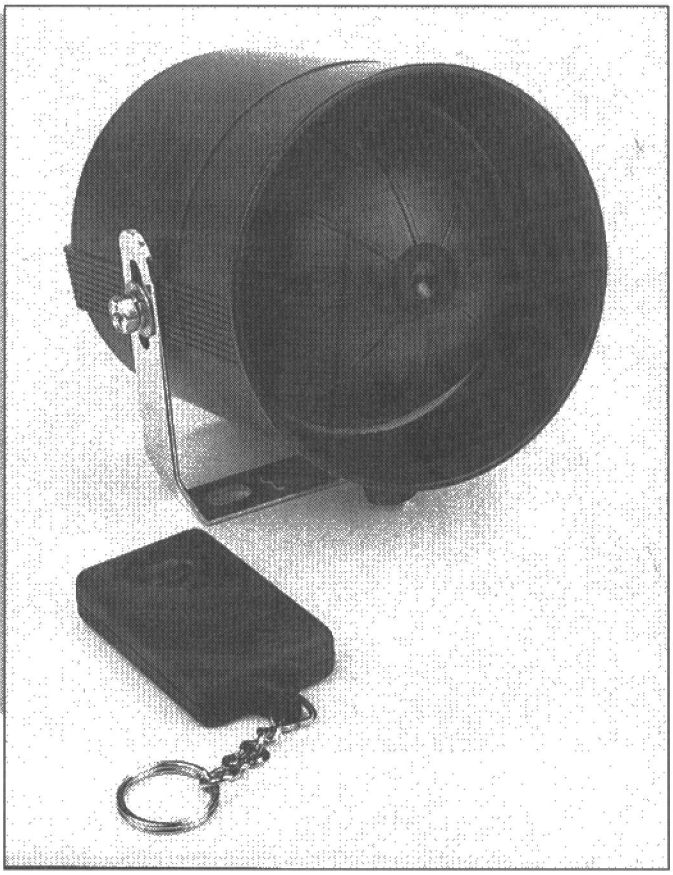
For more information contact Alpha Electronics on 0942 873434

New car alarm from Maplin

Maplin Electronics has just launched a new low-cost car alarm system, which it claims has more features than many more expensive models. The system is easy to fit with a two wire installation and will alarm and protect the vehicle. It is programmed with a remote control code and has a third wire which can be connected to the ignition switch so that the alarm can not be armed while the engine is running.

If the car is broken in to, the alarm will be triggered. A forced entry will turn on an interior light and then any sudden shock will start the alarm. The alarm has a 'warn-away' feature which is set by pressing the remote control button twice. When the shock sensor is triggered, a warning tone will tell the intruder to back off. If the shock sensor is triggered more than twice within 15 seconds the full alarm will be triggered.

The car alarm kit costs £29.95 and comes with all components, instructions, remote transmitter and warning stickers. It is available from any Maplin shop or by mail order. Maplin can be contacted on 0702 554161.



Mercury containing copper oxide becomes superconductive

By subjecting a mercury-containing copper oxide to very high pressures, scientists at the University of Houston have caused it to become superconducting at unusually high temperatures - above 150K (-123C). Currently, the highest ambient-pressure superconducting transition temperature on record is 135K. It was measured in the recently discovered compound HgBa2Ca2Cu3O8+8 by Houston physicist Ching-Wu Chu and co-workers.

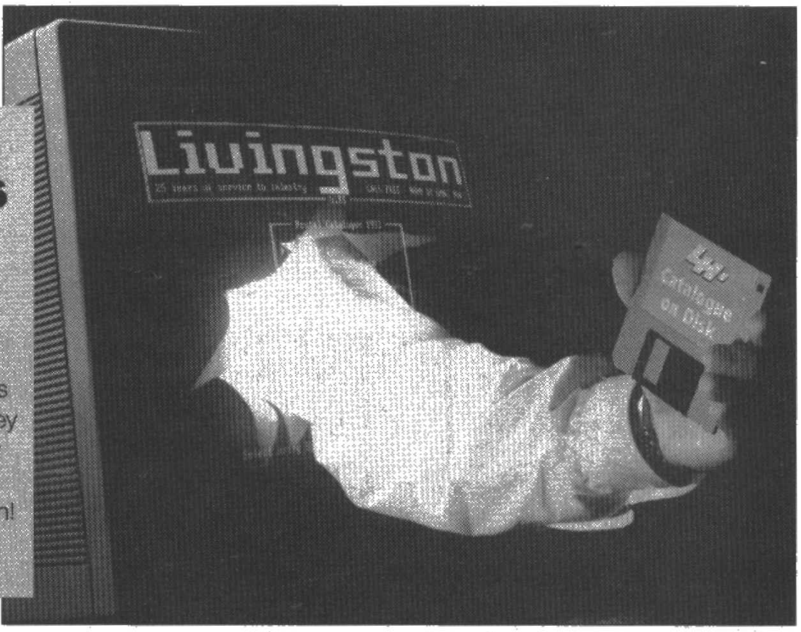
When Chu's group subsequently subjected this material to 150 kilobars of pressure (almost 150,000 atmospheres), its transition temperature went up to 153K. The researchers measured a transition temperature of 160K at 280 kbar. These results show subsequently that superconductivity in such layered cuprates is possible at temperatures researchers could once only dream of.

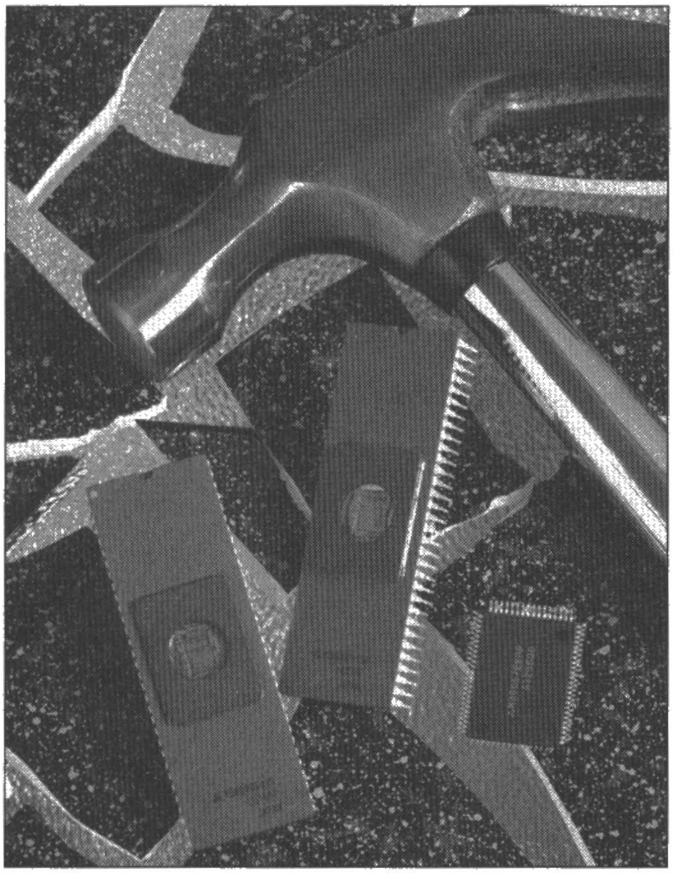
Because pressurising these superconductors is not technically feasible, Chu's team is seeking to duplicate this transition temperature enhancement effect at ambient temperatures using chemical means. One possible route, for example, is to replace the mercury with other elements that have linear oxygen co-ordination and/or a valence of 3 or less.

Disk based catalogue simplifies equipment rental

The well known electronic equipment rental company, Livingston Hire, has taken the unusual step of producing its rental catalogue on disk for PC users. This idea should enable users of the company's services to quickly and easily select the equipment they need. The disk also includes up to date details of new products available for rental and new services.

Catalogues on disk is an idea which could catch on! For more information, contact Livingstone Hire on 081 943 5151.





New microcontrollers from Mitsubishi

Mitsubishi has expanded its 38000 Series range of 8 bit microcontrollers to give a range of devices that should suit the needs of every designer. The 'mix and match' RAM and RAM concept range now incorporates devices carrying between 8 and 48Kb of ROM, with up to 1Kb of RAM.

The Series can be divided into three main groups - general purpose, VFD and LCD controller types. Features include a simple instruction set with 71 basic instructions, together with ROM, RAM and I/O addresses residing in the same memory map for easy programming. The single chip CMOS microcontrollers boast fast instruction times and the devices operate from power supplies between 2.5 and 5.5V, according to type

On chip functions include 16 vectored interrupts with up to 7 external interrupts and four 8 bit timers, three 8 bit prescalers, plus one USART and between 58 and 74 programmable I/O lines. On some chips, internal A/D converters are also provided offering 8 bit successive approximation conversion, with conversion in 50 clock cycles. The 8 bit DAC is an R-2R ladder network with external reference voltage. Clock rates are up to 6.8MHz.

For more information on the 38000 Series microcontrollers contact Mitsubishi in Hatfield, Herts, on 0707 276100.

Quantum, Connor roll out new disk drives

Two leading US manufacturers of disk drives, Connor Peripherals Inc., and Quantum Corp., have launched a new range of 2.5 and 3.5in models.

Connor has unveiled 2.1 and 1Gb 3.5in drives for use in servers, RAID subsystems and workstations. The two models, both in the Filepro range, have average access times of 9 and 9.5ms and consume 6.6 and 9.6W whilst idling.

In the 2.5in notebook-systems market, Connor has unveiled 340, 250 and 170Mb drives that weigh only 7oz apiece. They consume 1W while idling and have average seek times of 12ms. Shock resistance is higher than in most other drives - 300Gs in a non operating mode.

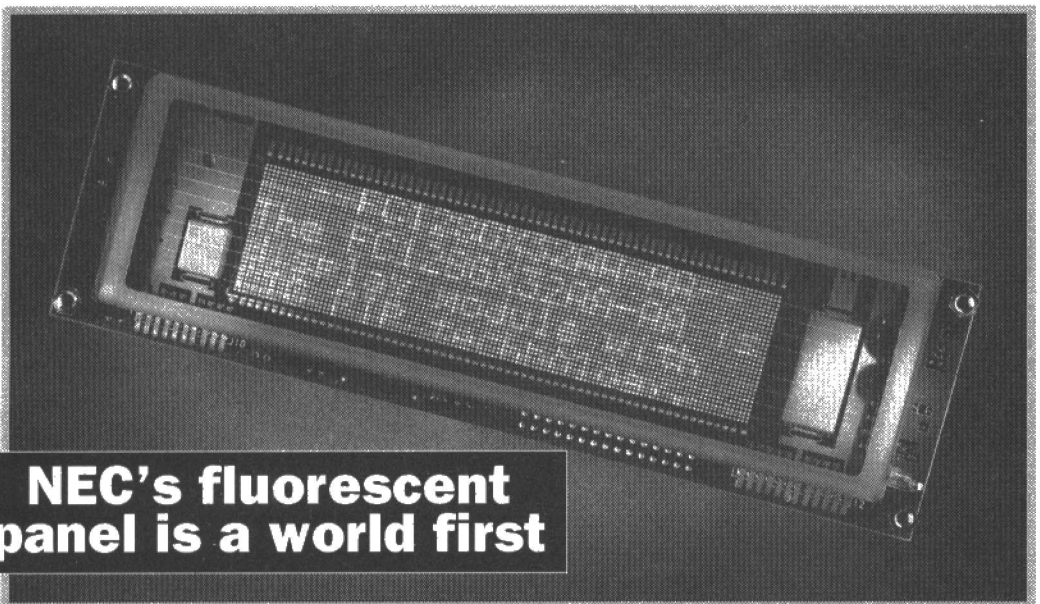
Quantum, for its part, is sticking to the desktop with an inch- high drive that stores 1.08Gb. The firm, which unveiled a 2Gb product a few months ago, says that the new member of its drive family has a 5,400 rpm rotational rate and a 9.5ms average seek time. Power consumption is 7.5W at a 30 per cent seek level, one of the lowest in the industry, Quantum said. While idling, the power rating is 6W.

Multichip module

A device claimed to be the world's first electro-fluidic multichip module should have a big impact in areas such as instrumentation and process control. The tiny modules, which link several silicon micro-machined components, control fluid flow from 0.1 to 1,500 cc/min (20psid) with an accuracy of 1% full scale.

Redwood Microsystems Inc., of Menlo Park, California, the firm behind these new devices, says the modules are smaller, more accurate and less expensive than regulators normally used to control non-corrosive gases in analytical and medical instruments.

Each module contains a silicon micro-machined sensor, drive electronics, flow connectors and one of Redwood's patented Fluistors, a new type of microvalve etched in silicon. When combined with Redwood's analogue control boards, the modules facilitate the design of closed-loop proportional controllers that precisely regulate pressures from 0-30 and 0-100psig.



NEC's fluorescent panel is a world first

NEC Electronics' new chip-in-glass fluorescent indicator panel is the first such display to include the driver ICs on the display substrate, dramatically reducing the module size and the number of lead terminals. Thus the new 128 x 32 dot graphics fluorescent indicator panel is 60% smaller and has just 22 lead terminals, as opposed to 198 for the conventional types.

These new displays will be used in applications such as industrial and medical equipment, office automation, alarm panels, test instrumentation and data terminals. Applications where smaller size and increased reliability are important.

The display module includes an 8 bit microcomputer, a character generator, power supplies and reset circuitry. The microcomputer reads, stores and edits the display data, and generates all timing signals. The character generator transforms the microcomputer output into 5 x 7 dot patterns. The power supplies change the 5V module supply into power for the anode, grid and AC for the display filaments.

For more information contact NEC Electronics in Milton Keynes, on 0908 691133.

Ground breaking digital video recorder from Samsung

Using green light laser technology, developed by the Russian military, the Korean electronics giant Samsung has designed a revolutionary magneto-optic erasable CD, which has sufficient capacity to store a full length film on a single disk. As a domestic TV recording technology it looks likely to set a new standard which will make obsolete conventional VHS tape systems.

Each side of a standard 13cm CD will be able to record 55 minutes of video, about 25Gb of data per side. This is an enormous increase on conventional CDs, which store 600Mb on just one side. The increased capacity is due to the much smaller track dimensions, made possible because green laser light has a much shorter wavelength than that of the infrared lasers used on standard CDs.

Motion computers

Motion computers, designed for specific motors, are changing the face of automation. Faster chips not only provide more accurate moves, but they also generate profiles that are nearly impossible using mechanical means alone. Two such chips, one for servos and another for steppers, are now being marketed.

One chip, actually a chipset, is from Performance Motion Devices Inc., of Chelmsford, Massachusetts. The DSP-based MC1401, one of the most advanced servo-control chipsets for its price, offers 32 bits of compute power for calculating position, velocity, acceleration, and jerk. Its four built-in profile modes, trapezoidal, velocity-contouring, S-curve and electronic gear - let it generate practically any complex move in real time.

Input features include support for an increment encoder with index pulse, two directional limit switches and a home signal. The chipset also features a choice of two digital filters - PID and PIVff (velocity feed forward) - and a period register that stabilises the response at low speeds. All filter and profile parameters can be changed on the fly to facilitate multi-axis synchronised motion, based on pulse-width modulation or 160 bit D/A converter compatible motor output signals.

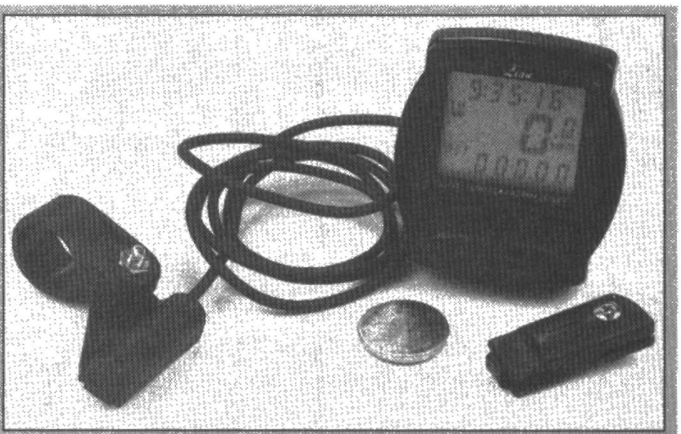
For stepper motors, the new model is the SMC-50, a single-chip microcontroller from Advanced Micro Systems Inc., of Nashua, New Hampshire. The SMC-50 calculates up to 50,000 steps per second. It supports full, half and microstep drivers, providing absolute or relative position commands with independent ramping in either direction (accelerating or decelerating).

Three-in-one cycle computer from Maplin

Maplin has launched a new product which should be of considerable interest to cycle owners. It is a compact multifunction computer which displays time, speed and distance on a 33 x 23mm LCD display. Speed and distance are calculated from the output of a wheel mounted sensor, making allowance for wheel size.

The time function can also be selected to provide a 24 hour clock, a journey timer, or a trip timer. The speed function can be selected to give actual speed, average speed, or maximum speed and the distance function can be selected to give trip distance or total distance.

The system is easily fitted, being provided with a handlebar mounting base and the main unit can be easily removed for security. The cycle computer can be obtained from any Maplin shop or by mail order price £19.95. Maplin can be contacted on 0702 554161.



Prototype superconductor to be built

The US Department of Energy has awarded a major contract for a two year project to an industry team that will build and demonstrate a novel superconducting current limiter prototype device for use by electric utilities.

The DOE, under its Superconductivity Partnership Initiative, will give $2.3 million to a collaborative team from General Dynamics Space Systems Division, American Superconductor Corp. and Southern California Edison Co. The remaining $1.1 million will be provided by the partners. In addition, Los Alamos National Laboratory will receive funding under a separate agreement to provide technical support.

A current limiter protects expensive electrical equipment by momentarily reducing the flow of excessive current caused by short circuits, lightning strikes, or common power fluctuations. Incorporating newly developed high temperature superconducting wire technology in the prototype current limiter will allow utilities to use smaller, less expensive circuit breakers and fuses, thus lowering their replacement cost.

Southern California Edison Co. estimates it could save $7.5 million a year by using the superconducting current limiter in its power grid alone. U.S. utilities potentially could save $100 million per year.

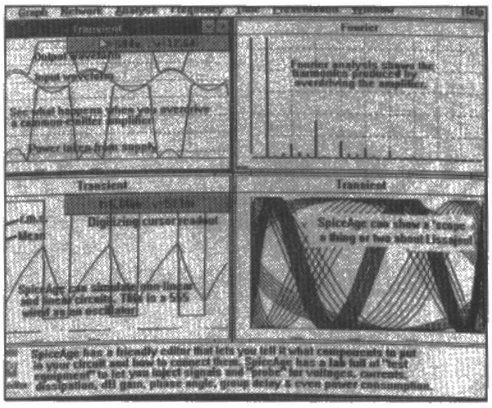
Fast PC based analogue simulation

The new version of the analogue circuit simulation software, SpiceAge, from Those Engineers Ltd is over 55% faster and is believed to be the fastest Windows based simulator available today.

The new version, V2.080, offers users some important new features including a DDE interface (supported by a self running demonstration/batch running utility), extra SPICE compatible .MOdels, and even better links to the GESCA schematic entry system. There are also a great many other improvements and additions.

SpiceAge for Windows has been written by British author Graham Baxter and produced by Those Engineers Ltd, a company that has specialised in circuit simulation software since 1982. It gives users access to a 'lab full of test equipment', which can be used to test analogue circuit designs. Users can inject signals, and 'probe' for voltages, currents, dissipation, dB gain, phase angle, group delay, and power consumption.

For more information on SpiceAge, contact Those Engineers Ltd on 081 906 0155.



Fourier analysis shows the harmonics produced by overdriving the amplifier.

See what happens when you overdrive a common emitter amplifier

SpiceAge can simulate non linear and linear circuits. This is a 555 wired as an oscillator.

SpiceAge can show a 'scope a thing or two about Lissajou

SpiceAge has a friendly editor that lets you tell it what components to put in your circuit and how to connect them. SpiceAge has a lab full of "test equipment" to let you inject signals and "probe" for voltages, currents, dissipation, dB gain, phase angle, group delay & even power consumption.

March of the micromachines

Around the world, increasing amounts of money are being spent on the techniques for developing machines with dimensions measured in millionths of a meter.

These micromachines are built using the same techniques employed to construct integrated circuits. They are made from silicon using lithographic and etching techniques and can contain dozens of minute mechanical components, even microscopic electric motors, as well as electronic circuitry.

So convinced are researchers in the United States of the future importance of these micromachines, that the government, through the Advanced Research Project Agency, has provided significant support for one of the world's leading micromachine research centres, the Microelectronics Center of North Carolina or MCNC.

The MCNC was set up over 13 years ago to develop advanced semiconductor technology. Already it has produced devices for fifteen separate clients, ranging from defence contractors to a high school, and with expenditures starting as low as $500.

Continued on page 12

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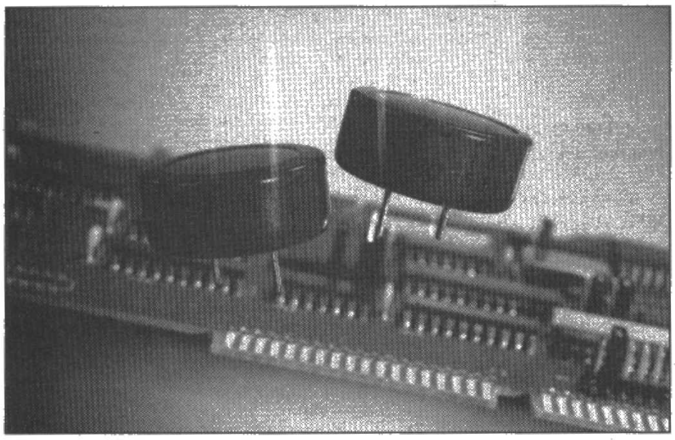
Environmental noise analyser from Castle

Environmental noise is now widely accepted as being one of the most pervasive and aggravating forms of pollution. To help monitor noise pollutions and provide an analysis of it, Castle Associates of Scarborough has launched a new portable Noise Analyser, the GA122.

This hand held device can perform a wide range of different noise measurements using its built in microphone. It is fully waterproof and features a large 32 character display, which is backlit to allow operation in the dark.

The GA122 has one megabit of internal memory for data logging and this is backed up by a lithium battery, which should provide up to five years memory retention. This data can be downloaded to a PC via an RS232 link, and then formatted on the PC to a suitable style and format, using dBdata 4W for Windows, a computer package specifically designed by Castle for the GA122.

The GA122 Logging/Integrating Sound Level Meter costs £2,680 complete with software. For further details contact Castle Associates on 0723 584250.



Capacitors as a source of backup power

Electronics giant NEC has just launched a range of capacitors which have been specifically designed to provide backup power for devices such as random access memory chips.

The new Supercaps family have capacitances as high as 3.1F and are currently available in 5.5V and 11V versions. Since a CMOS system only requires tens of microamps to operate in standby mode, it is thus possible to replace a stand-by battery with a large value capacitor to provide enough power to cover even prolonged power supply failure. Thus, a 256Kbit RAM can, according to NEC, be supported for 50 hours by a 2.2F Supercap.

Reserve power supplies based on capacitors are easier to implement than battery based supplies. The capacitor simply being connected across the supply with a current-limiting resistor and diode to isolate it from the primary power supply. It is also a lot more reliable, as a capacitor will stand an infinite number of charge/discharge cycles, while a NiCd battery will survive only a few hundred.

For more information on Supercaps contact NEC on 0908 691133.

New lab power supply from O & S

From Cheshunt based O&S Laboratory Products, comes a new stabilised electronic power supply which provides a voltage range of 0-30V DC continuously variable, together with an amperage range of 0-3A. The ranges are indicated in either analogue or digital display.

The unit is mains powered and comes with a carrying handle to make it easily portable. For further details contact O&S Laboratory Products on 0992 637373.

Europe and US go for digital broadcasting.

Over the last eight years, the EEC and Europe's big TV manufacturers, the likes of Philips and Thomson, have invested around £500million in the development of high definition television (HDTV). The European development was aimed at creating a standard system based on traditional analogue broadcasting technology, an approach followed by the Japanese with even greater investment.

The US government and US consumer electronics companies started development of HDTV at a later date than the other two main players, and they also took a different approach. What US developers have done is look at an entirely new way of broadcasting TV images - the use of digital technology. This approach allows TV broadcasting to be merged with computing and telecommunications technologies.

It has been so successful that the European companies and their backers in the EEC have now abandoned their previous proposals in favour of a digital system, similar to that developed in the US. Even the Japanese are now acknowledging that they have made a fundamental mistake and are embarking on a crash development of a digital HDTV system.

The Spark of Ingenuity

People all over the world are becoming increasingly aware of the impact that modern society is having on the environment, an impact which ranges from the effect of vehicle exhaust pollution, to the destruction of the protective ozone layer and global warming, from excessive reliance on fossil fuels, to the problem of excessive noise.

It has to be said that most of the problems we now face with environmental destruction and pollution of one sort or another are directly attributable to a combination of technological development and over population. But it must also be said that they are problems which can be overcome with the aid of human ingenuity and the application of technology.

Alternative energy to the rescue?

Probably the biggest impact on the environment comes from the enormous use of energy in a modern technology based society. Energy for transport, for heating, for powering all the gadgets which we take for granted in our homes and workplace. Energy which we use inefficiently and which comes from mineral resources which are not replaceable.

Inefficiently used fossil energy is a prime polluter, leading to hydrocarbons and CO2 in the atmosphere, acid rain, etc., but this is something which technology can help to solve. We can create systems which use energy more efficiently, and we can create systems which generate energy using renewable non-polluting resources. So called alternative energy sources.

Some of the most important sources of alternative energy are the wind and the sun and efficiently harnessing these energy sources is a subject which has attracted a lot of research over the last few years. Solar energy systems to have become much more efficient and dropped in price enormously, the same has been true to a lesser degree for wind power. Indeed, the amount of research has been sufficient that both solar and wind power systems are now serious contenders for power generation in many parts of the world, particularly the more remote areas.

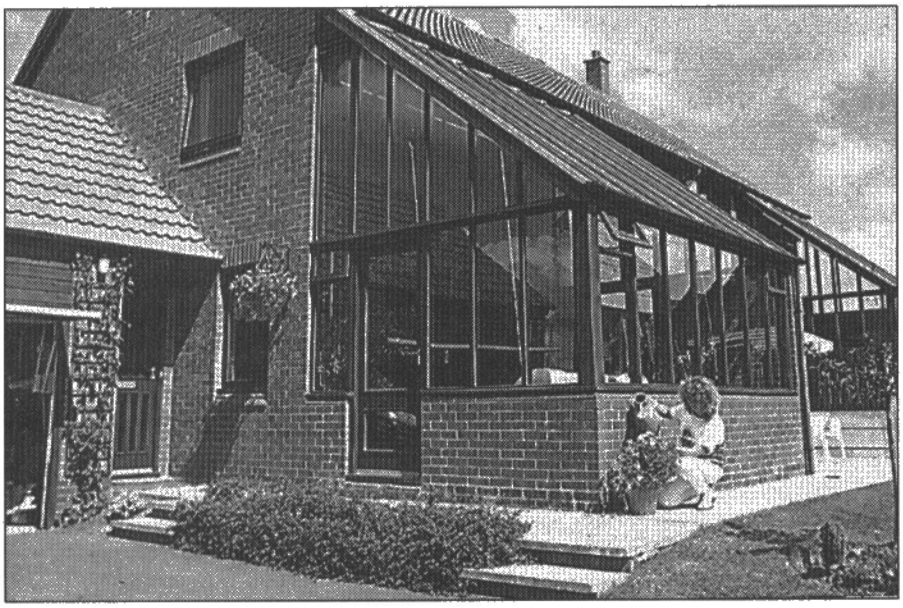
In the last decade wind generators have more than doubled in efficiency and their cost has been reduced by a factor of three. Solar energy systems have seen their efficiencies more than quadrupling, and the cost of generating a unit of solar electricity dropping by over 90%.

However, increased efficiency and declining costs have not been sufficient to promote the mass building of solar and wind power plants, and are unlikely to do so for many years to come. The reason is that not all parts of the world are suitable for siting such alternative energy power plants. Also, they require a lot of land on which to place large solar arrays, or windmill farms. This means that they need to be put in remote areas, far away from the centres of human habitation and thereby incur enormous overheads in both cost and power loss in power transmission between the generating site and the users.

What this means is that the use of alternative energy will be different to the use of more conventional energy. Instead of having large centralised power plants and a national grid of electricity transmission lines, alternative energy power plants will be much smaller and tailored to the needs of the individual or the local community. Every house may have its own wind generator and/or solar panels, power sources which, with good insulation and increased efficiency, should be adequate to provide a large percentage of the energy requirements of a household. Indeed, in Denmark, one of the world's leading users of wind power, over 2% of the national power requirement is already met by home based wind generators.

It is the fact that alternative energy systems are probably best applied on a small scale that makes them of particular interest to the electronics hobbyist. A wind generator or solar panel costing a few hundred pounds can provide enough power for a caravan, or considerably cut down domestic electricity bills. On a smaller scale, these technologies could be used to provide lighting, and limited power, for a garage, garden shed or greenhouse, etc.

There is no reason why we should not all have some form of alternative energy generation system. For a modest outlay we can save money (it takes about ten years to pay back the cost of an alternative energy system, after which all the power it generates is free!), and also do our bit to improve the environment by reducing our reliance upon fossil fuels. But don't expect to find such equipment in high street shops, they are not yet considered 'commercial products'. Instead you will have to sit down and design and build your own.



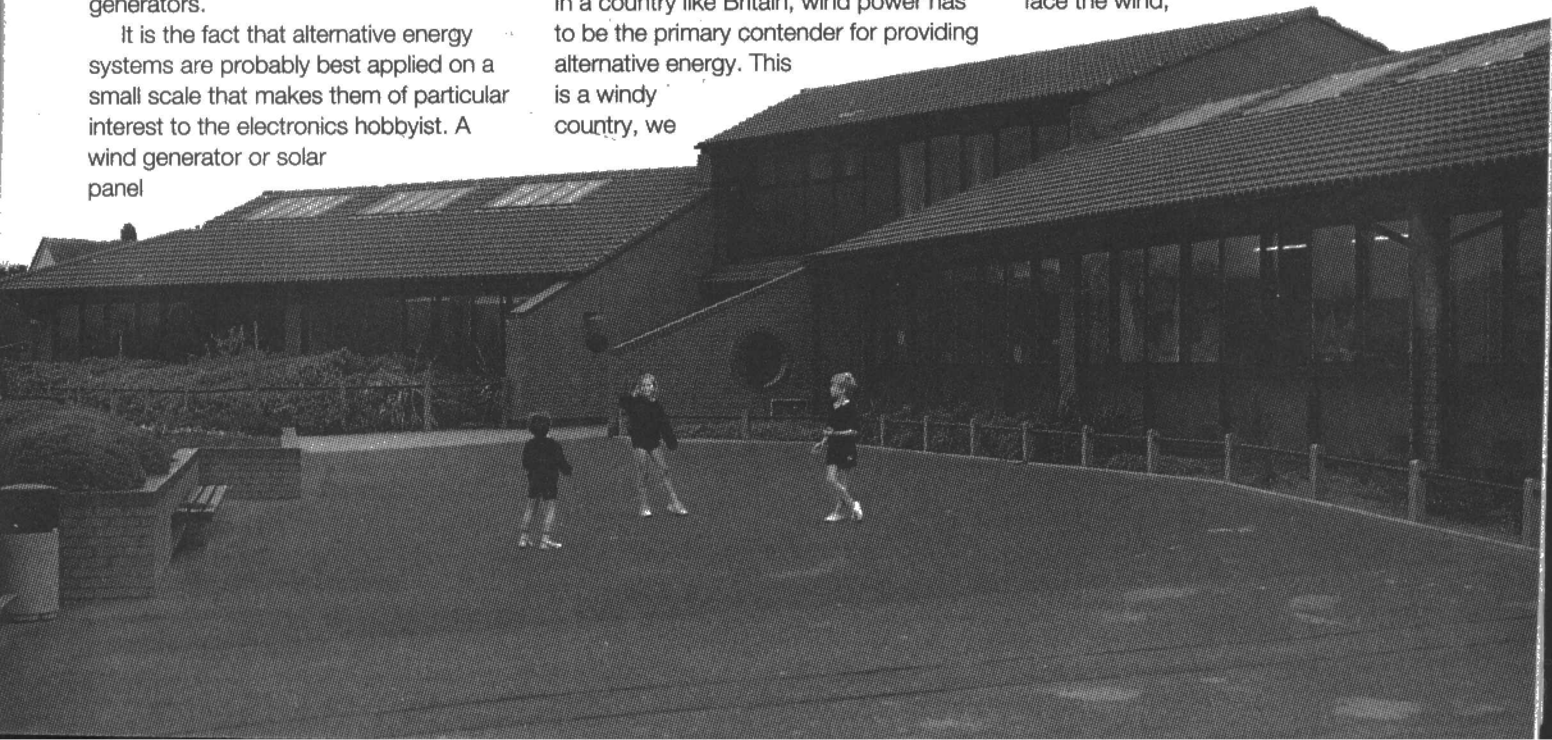
Electricity from wind.

In a country like Britain, wind power has to be the primary contender for providing alternative energy. This is a windy country, we receive over 40% of Europe's total wind energy potential. Already there are commercial wind farms generating electricity for the National Grid. These can be found in the remoter parts of the UK, in Cornwall, Wales and Scotland, and include one of the largest wind turbines in the world.

So how do we convert wind energy into electrical energy? The answer is, of course, our old friend the windmill. Not the windmills of Don Quixote, Texas ranches, or Dutch paintings, but modern high efficiency designs, based on aerodynamics and computer simulations. Instead of grinding grain or pumping water, these modern windmills are turning high efficiency generators to produce electricity.

The design of a modern windmill, or wind turbine as we should more correctly refer to it, is intended to extract the maximum energy from the wind while at the same time not succumbing to potentially disastrous problems such as vibration. Since the power output from an electrical generator increases in relation to the speed of the shaft's rotation (up to a maximum design level) it is important that the design works at as high a speed as possible in light wind conditions, while at the same time being able to withstand gale force winds.

The wind turbine can have a rotational axis which is either horizontal or vertical. The traditional windmill has a horizontal rotational axis with two or more propeller type blades. Vertical rotational axis wind turbines are much more recent and unfortunately still prone to structural and control problems, and are also less efficient than the traditional horizontal turbine. The only drawback with a horizontal axis system is that it must always face the wind,



although the traditional use of a wind vane is more than adequate to ensure correct positioning.

The favourite configuration for a modern wind turbine is to have two blades since, this produces the highest rotational speed. The blades have an aerofoil section, much like an aircraft wing, indeed some of the larger wind turbines look rather like a rotating glider. The ideal design will achieve a balance between maximum lift and minimum drag, with the aim of ensuring stability and a rotational speed which is about ten times faster than the wind speed. They are also designed to start producing power with wind speeds of just under 4 metres per second, considerably less than the average annual wind speed for any part of the UK.

The mechanical power output from a given turbine is proportional to the square of the blade diameter. This means that a 6ft diameter turbine will actually produce four times as much power as a 3ft diameter turbine. However, electrical power output is also proportional to the rotational speed of the turbine. This means that in order to achieve maximum electrical power output, it is usually necessary to use gearing to increase speed, with consequent power losses due to friction, etc.

The problem with wind is that it is a variable energy source. In still air, even the most aerodynamically efficient turbine will hardly be rotating, whilst in a gale it may be rotating at a dangerously high speed. This means that on all but the smallest wind turbines, some form of control is required to protect the system from damage in high winds. On large commercial turbines this control is provided by a computer, which amongst other things will feather the turbine blades, on small systems some form of manual or automatic clutch mechanism is essential.

Solar electricity

The big problem with solar energy as a source of alternative electrical power in the UK is that we have so few days per annum of bright sunshine. Modern solar cells will actually generate power output

The economics of alternative energy

As we have already seen, the complete system generating, storing, and outputting electricity in a usable form is quite complex, irrespective of whether the power is being generated by the sun or the wind. We can divide this system into four components - the generator, the power regulator, power storage and power output inverter. In order to consider the overall cost of a complete system, we need to look at the cost of each of these components.

If we look at designing a power system capable of delivering a mains voltage with a maximum power rating of 100W for at least seven hours per day, in other words, sufficient to light one medium power light bulb, run a small TV, fridge, computer, etc., then to calculate the cost we need to work backwards, and start with the inverter. A suitable solid state inverter with this sort of rating could be built for about £50, the major cost being the transformer, Savings can be made if one can be salvaged from other equipment.

The inverter draws its power directly from the batteries and these have to have sufficient capacity to cope with continued power use over periods of no sun or wind. In practical systems this means that the batteries should have a reserve of about five to ten days power consumption. We can calculate the total usable capacity for a 12V battery system as follows:

$$Ah = Wh \times T/12v$$

where Ah is the total usable capacity needed in Amp hours at 12V, Wh is the daily power requirement in Watt hours per day, and T is the storage period in days. In the case of our design requirement of 700Wh per day and five days reserve, the total usable capacity is 291 Amp Hours.

From this we can calculate the total number of batteries needed using the following formula:

$$N = (Ah \times 100/F)/D$$

in the previous equation), F is the full capacity specified for one 12V battery in Amp hours, and D is the maximum depth of the charge cycle in %. With the above design requirements, we need 4.4 12V lead acid batteries, where each battery has a total capacity of 110Ah and can be discharged to a depth of 60%.

The depth of the charge cycle is important. Batteries used for storage will probably spend long periods on partial charge, with consequent reduction in capacity of

Silicon solar cells

The majority of commercial solar cells are made from monocrystalline silicon that has been doped with boron. The thin slices of silicon, each about five inches in diameter, which are cut from the monocrystalline block are then exposed, in a furnace at 1500C, to a gas containing phosphorus. This creates a pn near the surface, between the boron doped substrate and the thin phosphorus doped surface layer. It is this pn junction which gives the slice of silicon its photovoltaic property of converting light into electricity.

After this treatment in the furnace, a network of metal strips is attached to the surface of the slice of silicon. This network forms the contact while a layer of metal on the back of the cell forms the positive contact. An anti-reflective coating is put on the front of the silicon slice which is now a solar cell ready to be mounted into an array.

Another type of silicon used to make solar cells is polycrystalline silicon. This is slightly less efficient at converting light into electricity, but is much cheaper to manufacture. It is easy enough to tell the difference between the two types by looking at them. Monocrystalline silicon solar cells have a uniform blue colour, whereas polycrystalline cells will show an irregular pattern, like that seen on a galvanised iron bucket.

There is, in addition, a third type of silicon solar cell which is gaining considerably in popularity, the amorphous silicon cell. Amorphous silicon, containing a small amount of hydrogen, is deposited on a conductive glass substrate, then doped in a furnace before having the other conductors added. This type of cell is much cheaper to make than the other two types and, although it has a lower efficiency, it can be made in much larger sizes, cells measuring 6 x 12in are not at all uncommon.

on quite dull days, but the power produced will only be a few percent of that produced on a bright sunny day. However, solar cells do have one major advantage over any other alternative energy source of electricity. This is that they are all solid state, with no mechanical components and thus extremely reliable, robust, and compact. Ideal for use in remote sites, such as unmanned lighthouses and telephone exchanges.

At the moment, there is only one real contender for the generation of solar electricity, the silicon solar cell (see box 2). Other types of solar cell under research are based on semiconductors, such as Gallium Arsenide and Cadmium Sulphide. Technologies based on organic pigments and an oxygen/hydrogen/water cycle incorporating fuel cells are a possibility for the more distant future.

A typical 4 x 2.5in monocrystalline solar cell will generate nearly 1V at 1/2A in full sunlight. Amorphous silicon solar cells have a lower efficiency, but single cells can be much larger. A typical amorphous cell might measure 12 x 6in and output 12V at 125mA. With both types of cell, higher voltages are generated by connecting numbers of cells in series and in parallel.

A typical solar electricity system thus consists of a number of cells wired together on a watertight, weatherproof panel, placed in an open sunny position. In the UK such a panel must be faced towards the south and inclined at an angle so that it faces the sun and receives the maximum solar energy input (a rule of thumb is that the angle of tilt should be about the same as the angle of latitude for the site).

Alternative energy systems.

The actual power generating component, in both wind and solar electrical power generation, form just one part of a larger system. The overall system must be able to generate electricity, store electricity so that it is available when needed and convert the low voltage DC battery output into a 240V AC mains output, which can be used by domestic and commercial equipment.

In a wind generator system the output

lead-acid batteries due to sulphation. As a result, it is advisable to use only high quality lead-acid lead acid batteries with a depth cycle less than 50% or vented nickel-cadmium batteries.

Using the above calculations we will need about 5 batteries. Depending on the source and whether they are new or second hand, these will cost at least £120 and perhaps as much as £300. This represents a considerable portion of the total investment in an alternative energy system.

Next, we come to the power regulation electronics. This just consists of a rectifier and voltage regulator, so, given the fairly low voltages and power ratings involved, can be constructed for just a few pounds.

Finally we come to the actual power generation part of the system. Here, the average power generated per day should balance the average power used per day with suitable allowance for losses during conversion and storage. So if we are using 700Wh per day, we will need at least 800Wh per day of generating capacity. Since wind power operates 24 hours per day, we are looking at an average power generation capability of about 36W. With solar power the practical generation period could be as little as three hours per day, leading to a requirement for a generating capability of about 200W.

With commercial solar panels costing in the region of £7 per watt of generating power, this means that our solar power system will cost about £1400 for the solar panels. Added to this is up to £250 for batteries, and £60 for other electronics and we reach a minimum system cost of at least £1710, not counting the cost of cables, mounting wood/metal work and labour for installation.

Given a workshop and the ability to make things, a suitable wind generator could be produced for about £100. A vehicle alternator could be used as the generator, the turbine blades can be made from plywood and the gearing can be achieved with the aid of a belt and pulleys. The total cost of a home made wind generator would be between £300 and £400.

Now we come to calculating the actual cost of the electricity generated by such alternative energy systems. Both are producing 0.7kW of power per day, or 0.7 units of electricity. With a single unit of electricity costing about 7.4 pence, this gives a payback period for a solar system of over 62 years, hardly what one would call an economic proposition, more a labour of love or conviction. A wind generating system, on the other hand has a payback period of just over ten years and, as such, is within the bounds of being an economic proposition as well as something one can do to help the environment.

from the generator will be a variable AC current, voltage and frequency, with output changing as wind speed and generator rotational speed changes. Because there will be times when there is no wind, or the amount of electricity being generated is insufficient to meet transitory power requirements, a battery must be used to store surplus power output. Such a battery system is connected across the power lines and in effect trickle charged, but power cannot be taken directly from the electric generator. It first needs to all be converted to DC by passing it through a rectifier and then have the voltage regulated so that there is no danger of applying excessive charging voltage to the batteries.

The batteries will probably store power at either 12 or 24V and some users of alternative energy systems make do with a low voltage DC power system. However, it is far more convenient to be able to use standard mains voltage equipment and this means converting low voltage DC into high voltage AC. Nowadays high efficiency (about 90%) solid state circuitry is used in inverters, as opposed to the old use of a motor/dynamo couple. An inverter basically just switches the DC input off and on at 50Hz and feeds it through a transformer, which converts 12V into 240V. Simple inverter circuits output a square wave, as opposed to the sinusoidal wave seen in standard AC mains power.

With solar power there is no need to rectify the voltage input from the solar cells, since it is already DC. Otherwise, there is exactly the same requirements for voltage regulation, battery power storage and, finally, the creation of 240V AC power by an inverter.

Is alternative energy practical?

The answer to this question has to be a qualified yes. In remote areas, alternative energy generation systems offer us the best way of bringing electrical power to individuals and communities located in such places. In densely populated cities, alternative energy is less economic and less practical. There is little room for siting large wind turbines or solar cell arrays, and placing them well away from the cities leads to power transmission losses.

But in a country like the UK, with large areas of suburban housing there is probably considerable scope for very small scale alternative energy generation systems attached to individual houses. If individuals in Denmark can produce over 2%, and rising, of the national power consumption then individuals in the UK can certainly do the same. It is an area which offers considerable scope for commercial development, and for the ingenuity of the individual.

Further information.

To find out more about the practical aspect of alternative energy systems, it is well worthwhile contacting the Centre for Alternative Technology, in Machynlleth, Powys.

For more information on the commercial aspect of renewable energy, contact ETSU for the Department of Trade and Industry at Harwell, Didcot, Oxfordshire.

There is a good practical book on solar energy called Solar Electricity by Simon Roberts and published by Prentice Hall. You could also refer to the large number of articles which have appeared over the last decade, in virtually every science and technology related publication.

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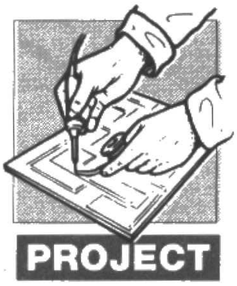
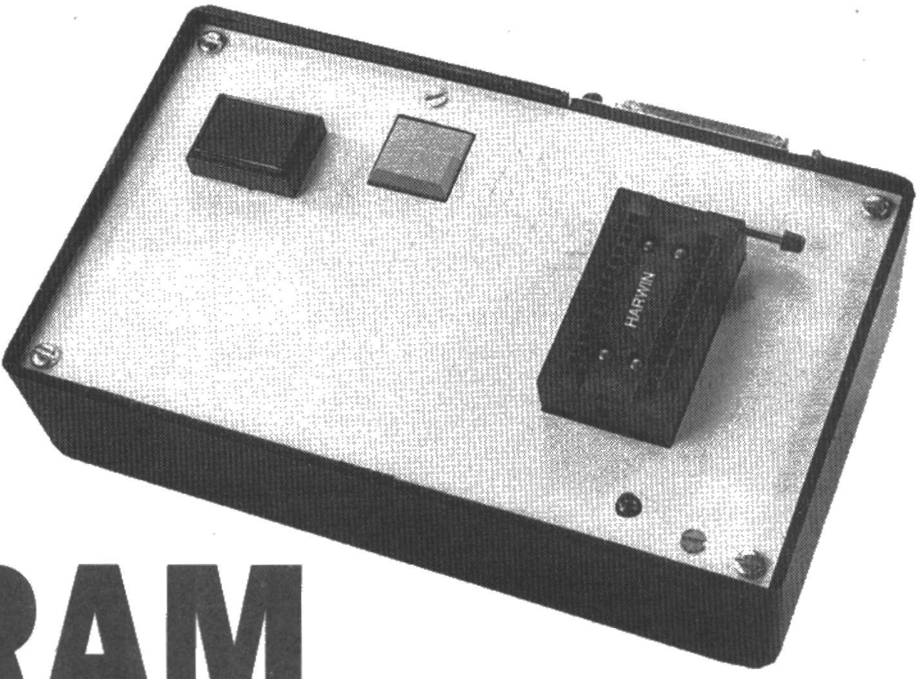


PROJECT



A low cost Non-volatile RAM programmer for microprocessor developers by Jason

ProgRAM

When developing code for stand alone micro processors, some form of EPROM emulator makes life a lot easier. Battery backed RAMs can be used in place of EPROMs, but programming them can be a problem. This is because most programmers first check that the memory is blank and refuse to continue if there are not, but ProgRAM provides a very low cost solution to this problem. It is designed to be plugged into the PC parallel printer port, although it should also operate from most parallel printer ports with the appropriate cable.

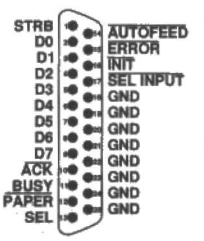


Fig.1 Centronics parallel port

Centronics Parallel Printer Port

Lets first look at the connection between the ProgRAM circuit and the computer. The standard Centronics printer connector is a special 36 way connector. Most PC compatibles, however, use a 25 way D-type connector. The pin out is shown in Figure 1. This unit connects directly to the 25 way connector.

To restrict the flow of information to slow mechanical printers, handshaking is used. First, assuming Busy is low, the data is placed on the data lines D0 to D7. Strobe is then taken low momentarily by the PC. The printer can latch the data on the falling or rising edge of this signal. The printer then takes Busy high until it is ready for more data. At this point ACKnowlege is pulsed low. This signal is useful for triggering an interrupt.

There are three other important signals. PE is taken high when the printer is out of paper. SEL is pulled high by the printer. ERR is taken low when an error occurs, e.g. out of paper, off line, jammed, etc.

How It works

To extract data from the printer port all the unit needs to do is assert the correct handshake signals. Figure 2 shows the handshake procedure and Figure 3 shows the circuit. The falling edge of strobe sets an SR flip-flop (IC2a), the output of which is connected to the Busy line. On the rising edge of strobe, the data is written into the NVRAM. The rising edge also triggers a monostable (IC1a), which produces a 10µS pulse. The falling edge of this pulse increments the address counters (IC4 and IC5), and also causes the Busy flip flop to be reset. In turn, the falling edge of the Busy line causes monostable IC1b to generate a 10µS ACK pulse.

The address counter is formed from IC4 and IC5. These dual 4 bit counters are connected to form a 16 bit counter, the high bit of the previous counter being used to clock the next counter.

ERR, SEL and /PE are tied to the appropriate levels, as described above.

The unit is reset by pressing S1. This toggles the Chip enable line of the RAM and resets the address counters to zero. When D2 is alight, the RAM is enabled.

A Switch is included, so 8Kb or 32Kb RAMs can be programmed. Close switch S2a and open S2b for 32Kb or vice versa for 8Kb RAMs. Some PCs have printer ports which can be programmed as inputs. If you know how to program them, it is possible to read ROMs with this unit by switching S2d on and S2c off (S2d off, and S2c on, in normal operation).

Construction

Construction is relatively straight forward if the PCB shown if Figure 4. is used. Insert the components in ascending size order and, when assembled, check the board for shorts caused by excess solder. Make sure the DIL switches are in the position required.

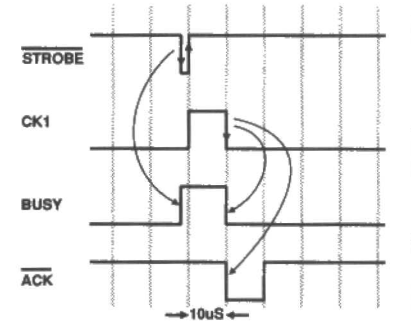


Fig.2 Handshake procedure

The type of ZIF socket used will depend on how the unit is to be cased, but the unit can be used without a box to keep the price low. In this case take care when purchasing the ZIF socket. The socket used in the first prototype was made by Harwin. The IC is locked by pushing the lever to the right

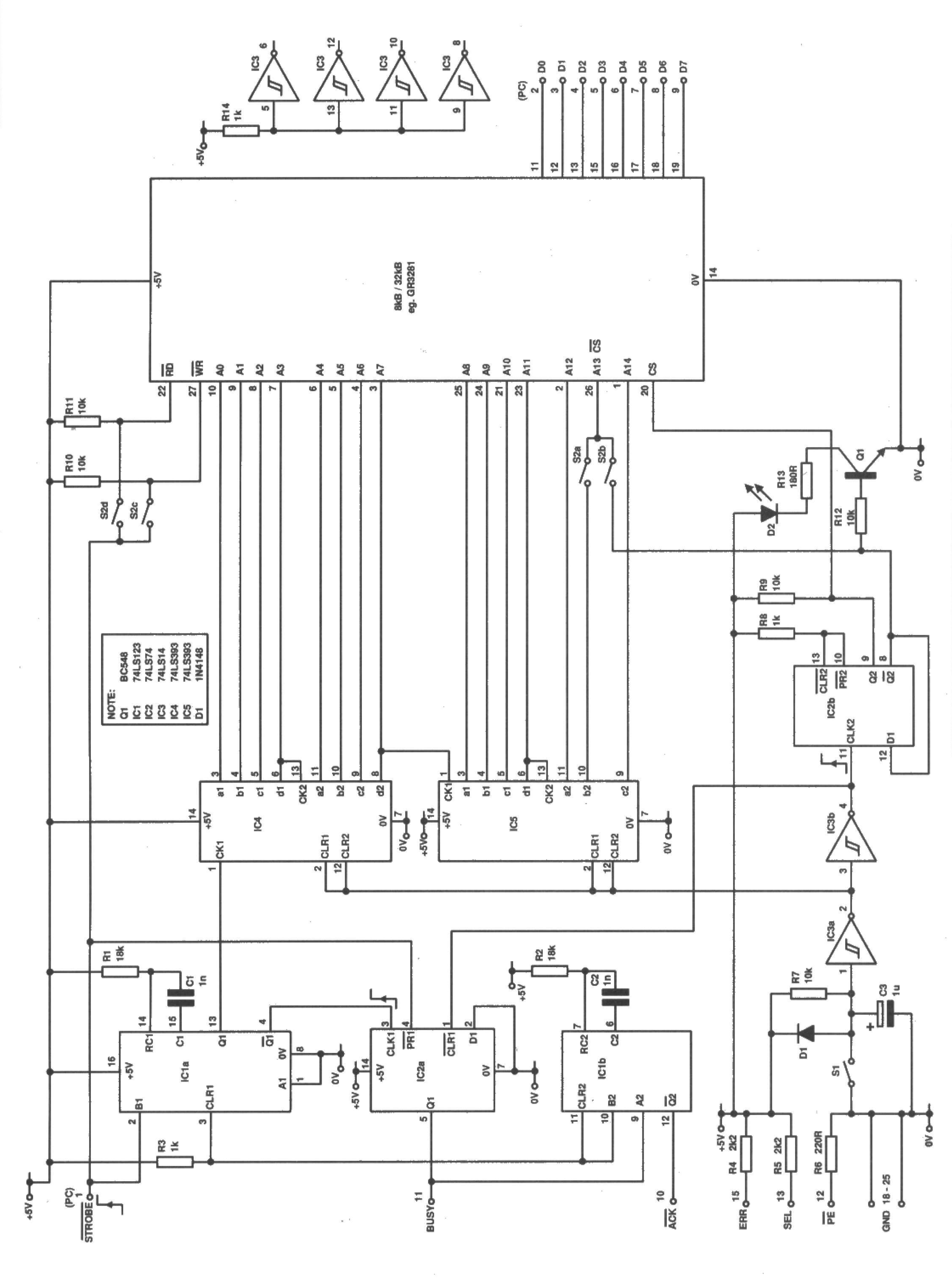


Fig.3 ProgRAM circuit

although some ZIF sockets, such as the one made by Textool, lock using a lever with upward motion. This type may catch on the 25 way socket. If the unit is to be mounted in a case, the ZIF can be elevated, so it protrudes from the front of the case, using a 28 pin wire wrap socket. The Harwin ZIF pushes into these sockets like an IC, the Textool one doesn't. It would require soldering.

Testing

Connect the unit to a stabilised 5V power supply. Connect the unit to the parallel port of the PC with a 25 way lead terminated with 25 way male connectors at each end. When the push button is pressed, the LED should toggle between on and off. When the LED is on, check that all of the address lines (A0-A14) are around zero volts. Single bytes can be sent to the port from BASIC using LPRINT chr$(char), where char is the value between 0 and 255 that will appear on the data lines. Each time an LPRINT is performed, the address should increment by one and the data specified will appear on the data lines.

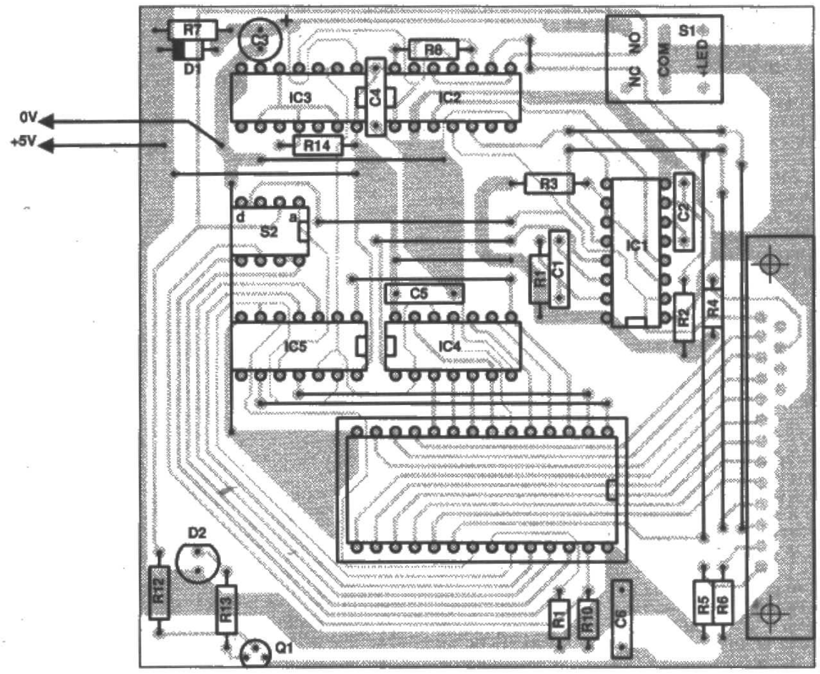


Fig.4 ProgRAM PCB and component overlay

Programming RAMs

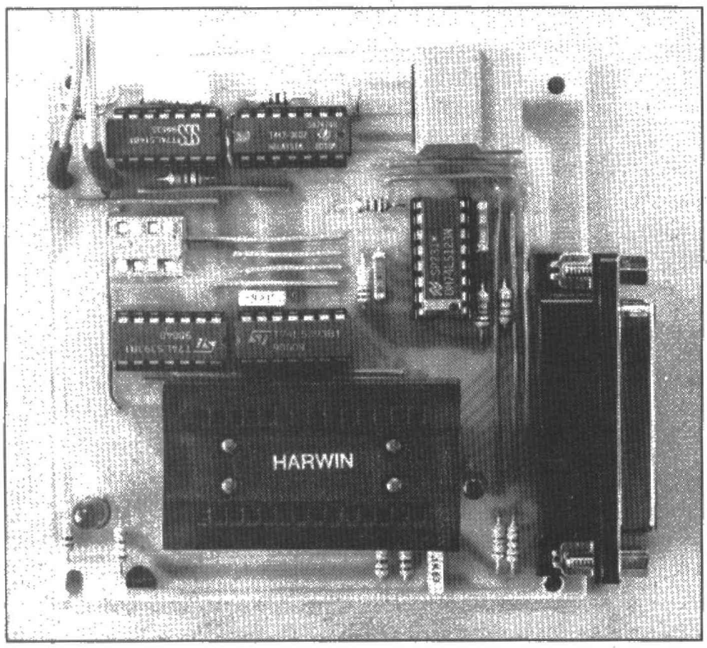
Several suppliers stock non-volatile SRAMs and most of these are ordinary SRAMs with a lithium battery and power down circuitry stuck on the top. The lithium batteries have an expected life of approximately 10 years. This should be remembered when you see cheap surplus devices advertised.

If you have a file containing the data you wish to program into the RAM, this can easily be done from MS-DOS. Turn ProgRAM's power off and insert the RAM. Restore power and press the button until the LED comes on. On power on, the unit is often in the correct state, but If the LED was on at power up, press the button twice anyway to make sure. At the DOS prompt type:

```
C:\> COPY file#LPT1:\b
```

This will program the RAM in three seconds or less, depending on the size of the file. The \b switch tells DOS to send a binary file. If omitted, only the data up to the first Control Z character will be sent. If CP/M is being used, PIP can perform a similar function to copy. From BASIC, LPRINT can be used to program bytes, as described above.

Note that if the program is larger than the capacity of the RAM, the address counters will loop and overwrite the data at the start. This could be prevented with some additional logic by using the highest bit of IC5 to disable the RAM.



PARTS LIST

CAPACITORS

C1,C2	1nF Poly.
C3	1uF Elect.
C4,C4,C6	0.1µF (Decoupling)

RESISTORS

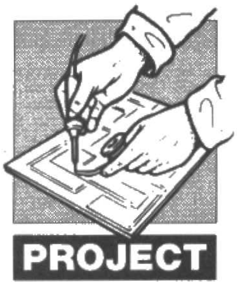
R1,R2	18k
R3,R8,R14	1k
R4,R5	2k2
R6	220R
R7,R9,R10-12	10k
R13	180R

SEMICONDUCTORS

TR1	BC548
D1	1N4148
IC1	74LS123 (dual monostable)
IC2	74LS74 (dual d-type)
IC3	74LS14
IC4,5	74LS393 (dual 4 bit counter)

MISCELLANEOUS

28 Pin Zif socket
4 way DIL switch (or solder links can be used).
Push button
25-D way socket, PCB mounting



Logic Pulse Generator

Build Robert Penfold's latest test project, a handy logic pulser

A logic probe is probably the most useful piece of inexpensive test gear for the logic circuit experimenter, but a logic pulser comes in as a close second.

A logic pulser is the digital equivalent of the audio engineer's sinewave/squarewave generator. In its most simple form, a pulse generator consists of a probe type device which produces a low frequency output signal at TTL logic levels. Some devices of this type also have the ability to produce a single output pulse each time a push-button is operated.

More sophisticated pulsers are in the form of normal bench units which can produce a wide range of output pulse durations and repetition rates. The most refined logic pulse generators have complex digital control circuits and can provide virtually any desired pulse waveform with an extremely high degree of accuracy, obtained by using a crystal reference oscillator to govern the timing of the output signal.

The pulser described in this project is a bench unit of the non-crystal controlled variety. It provides a wide range of output pulse durations and frequencies and although it lacks crystal precision, it is adequate for much logic testing and development work. There are separate TTL and 5V CMOS outputs so that the unit is fully compatibility with a wide range of logic circuits. Anti-phase outputs are available at both TTL and CMOS levels. The unit can therefore provide two-phase clock signals having virtually any desired mark-space ratio.

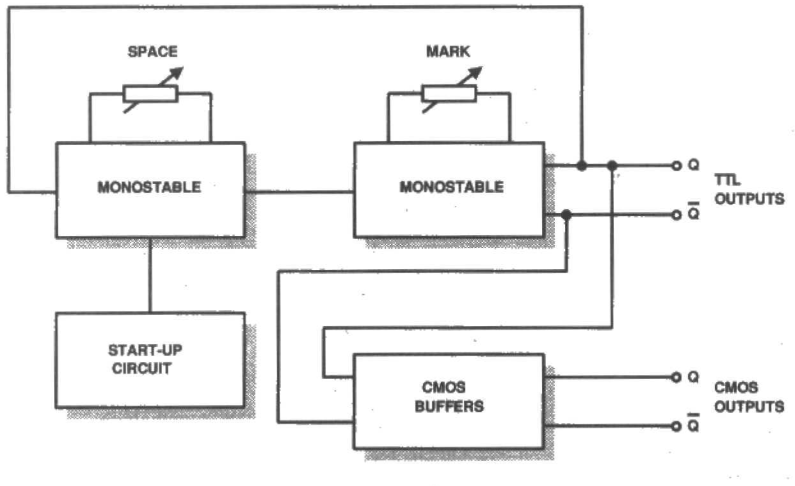


Fig. 1 Pulse Generator block diagram

Mark Time

Many pulse generators operate on the basis of having the user set an output pulse direction and a repetition frequency (e.g. a 10µs pulse at a frequency of 10kHz). This unit uses the alternative method of having the mark and space times individually adjustable. This sometimes requires a little more thought in order to get the required output signal, but with a little practice it becomes second nature.

In the example given above, a 10µs pulse rate of 10 kHz is clearly a 10µs pulse every 100µs. The mark time is therefore 10µs, and the space time is 90µs (100µs minus 10µs). The unit is easier to use if you think directly in terms of mark and space times, but it is not usually too difficult to convert pulse durations and frequencies into mark and space times.

An advantage of having adjustable mark and space durations is that there is no risk of accidentally setting a nonsensical output waveform, such as a 100ms pulse at a frequency of 1MHz. Any output waveform that can be set on the controls can actually be generated. The mark and space times are each adjustable from approximately 110ms to 1µs in five ranges, as follows.

Range 1	1µs to 11µs
Range 2	10µs to 110µs
Range 3	100µs to 1.1ms
Range 4	1ms to 11ms
Range 5	10ms to 110ms

This equates to a frequency range of about 4.5Hz with both times set at maximum, to 500kHz with them both set at the mimimum value. Clearly a very wide range of mark-space ratios are possible. In fact mark-space ratios as extreme as 100000:1 and 1:100000 can be generated.

System Operation

The circuit is based on two monostables which are used in a form of ring oscillator. The block diagram of Figure 1 helps to explain the way in which the unit functions. Both monostables operate in the negative edge triggered mode. In other words, they are triggered by high to low transitions at the trigger inputs. Once triggered, an output pulse is produced and the length of this pulse is controlled by a C-R timing circuit.

The Q output of the first monostable connects to the trigger input of the second monostable. Similarly, the Q output of the second monostable is coupled to the trigger input of the first one. As the output pulse from the first monostable finishes, it provides a negative edge which triggers the second monostable. When the output pulse from the second monostable ends, it produces a negative edge which triggers the first monostable. The circuit therefore oscillates indefinitely, with the two monostables continuously triggering each other.

There is a small flaw in an oscillator of this type in that it is not guaranteed to start-up at switch-on. In many cases this will happen due to the production of spurious trigger pulses, but initial triggering is dependent on how fast and how cleanly the supply is introduced to the circuit. To ensure correct starting every time, a crude but effective start-up trigger circuit is used to prod the first monostable into action.

Another slight fault with this type of oscillator is that overloads on the output can result in it stalling. In practice this is not likely to be a problem, since removing an overload is almost certain to trigger the oscillator back into action. However, if oscillation should be suppressed, simply switching the unit off and then turning it back on again will spur the circuit back into oscillation again.

A ring oscillator of this type is well suited to pulse generator applications because it gives easy control of the mark and space times. The mark duration (the time during which the Q output is high) is controlled by the timing circuit of the second monostable. The timing circuit of the first monostable controls the space duration. In Figure 1, the mark and space times are shown as being controlled via two variable resistors. In the practical circuit there are also five switched timing capacitors. These provide the unit with its five timing ranges for each output half cycle.

The circuit is based on a TTL dual monostable and this obviously provides outputs that are fully TTL compatible. The Q and not Q are fed to CMOS buffers in order to provide fully CMOS compatible outputs. Note that the unit has a 5V power supply and that the CMOS outputs are therefore at 5V logic levels. Consequently they are not compatible with CMOS circuits which operate at a supply potential of other than 5V.

The Circuit

The full circuit diagram for the pulse generator appears in Figure 2. IC1 is a 74LS221 dual monostable and this contains two identical monostable circuits which have positive and negative inputs. In this case the positive trigger inputs are not needed and are simply wired to the positive supply rail. Each monostable also has a reset input. Taking the appropriate reset input low results in output pulses being brought to an immediate end. Again, these two inputs are not required in the present applica-

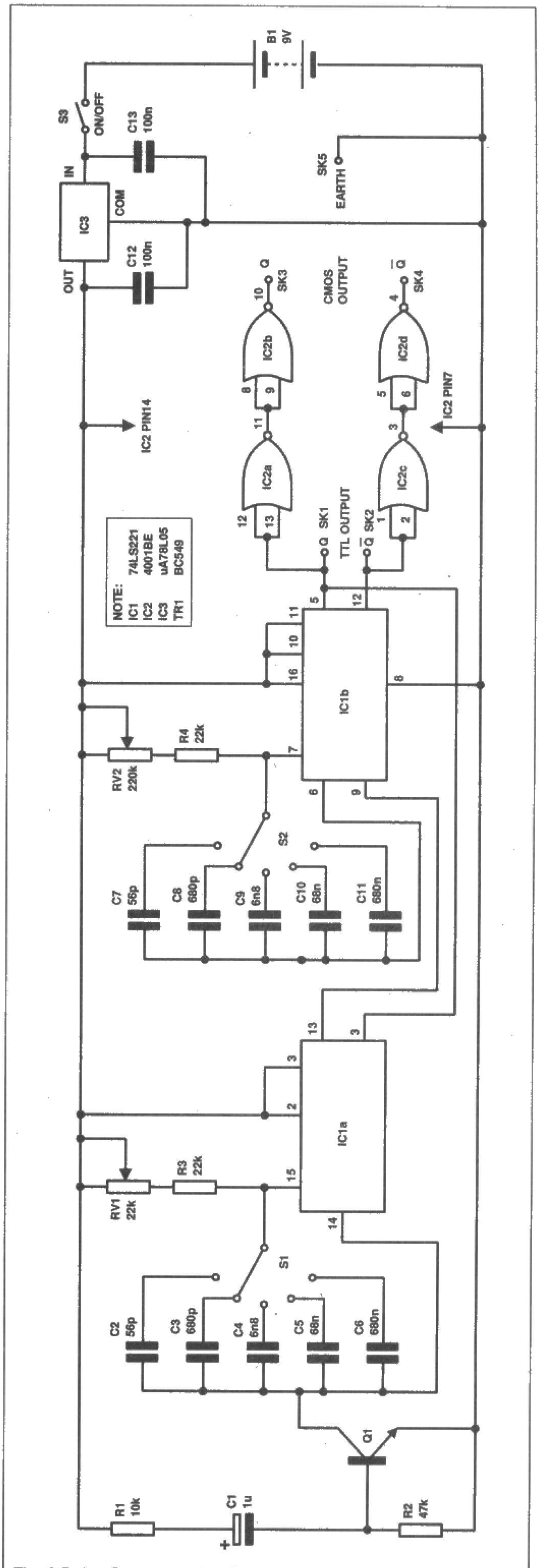
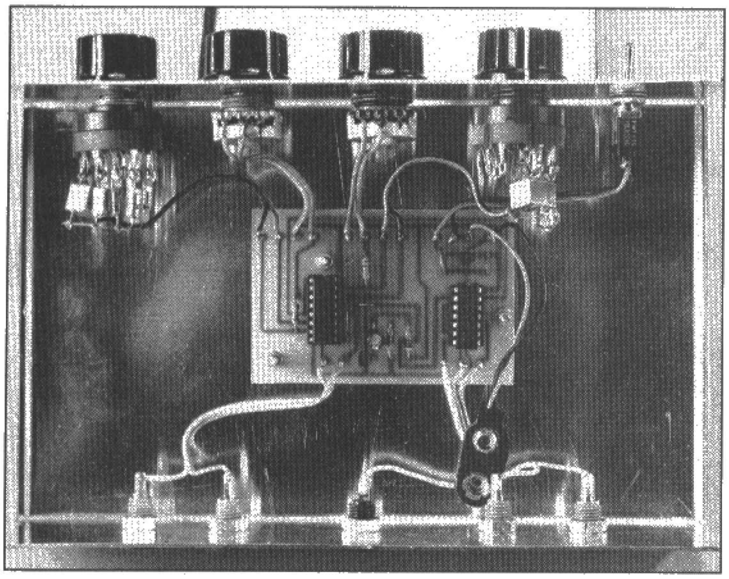


Fig. 2 Pulse Generator circuit



S1 and S2 are respectively the space and mark range switches. Each of these switches controls a bank of five timing capacitors. Although it might appear that C2 and C7 should have a value of 68p, a value of 56p does in fact give much better accuracy. The missing 12p of capacitance is provided by the self-capacitance of IC1. VR1 and R3 are the timing resistance for the first monostable - VR2 and R4 provide the same function in the second monostable. VR1 and VR2 enable the space and mark times to be adjusted over the approximate ranges specified previously.

TR1 is used in a simple timing circuit that briefly short circuits pin 14 of IC1 to earth at switch-on. This ensures that the circuit is spurred into oscillation at switch-on. IC2 provides the CMOS buffers, which are actually pairs of 2 input NOR gates wired to act as non-inverting buffers. The TTL and CMOS output signals are fed to separate pairs of output sockets, making all four output signals available simultaneously.

The circuit requires a well established 5V supply and this is obtained from a 9V battery via a small 5V monolithic voltage regulator (IC3). The supply current is about 15mA, which is high enough to necessitate the use of a medium capacity battery. Probably the best choice is six HP7 size cells in a plastic battery holder. There is no need to use any form of high power cells, and any cheap HP7 size cells should be perfectly adequate.

Construction

The diagram in Figure 3 shows the component layout for the pulse generator printed circuit board. IC2 is a CMOS device and the usual anti-static handling precautions should be taken when dealing with this component. This includes using a DIL integrated circuit holder for the device. In fact, I would recommend the use of a holder for IC1 as well. Do not overlook the two wires just to the right of IC1. Fit single-sided solder pins to the board at the seventeen points where connections to off-board components will be made.

The prototype is housed in an inexpensive metal instrument case which measures about 200 x 130 x 50mm. On the face of it this is far larger than is really necessary, but the five controls and five sockets need a fair amount of panel space, which precludes the use of a really small case. Even using a medium size case I found it necessary to relegate the five output sockets to the rear panel. I used 4mm sockets for SK1 to SK5, but practically any sockets are adequate for this application. The front panel layout is not particularly critical, but use one that avoids the need for a lot of long wires criss-crossing one another.

Mount the printed circuit board at roughly the middle of the base panel using plastic stand-offs, 6BA fixings, or metric M3 fittings. If 6BA or M3 fixings are used, spaces about 6 to 12mm long must be included, so that the connections on the underside of the circuit board are held well clear of the metal case. The hard wiring is then added. Details of this wiring are provided in Figure 4, which should be used in conjunction with Figure 3 (e.g. point A in Figure 3 connects to point A in Figure 4).

As will be apparent from Figure 4, the range capacitors are mounted on S1 and S2 and not on the printed circuit board. This minimises the amount of wiring from the circuit board to the controls, which in turn minimises stray capacitances.

Fitting the capacitors is easier if axial lead capacitors are used, rather than vertical mounting printed circuit types. It is possible to use printed circuit mounting capacitors, but it will probably be necessary to bend the lead out wires outwards at right angles before soldering them in position. The forming of the lead outs must be done very carefully, since the lead out wires are easily detached from many types of printed circuit mounting capacitor. The tags of the switches and the ends of the capacitors' lead out wires should be well tinned with solder, prior to fitting the capacitors onto the switches. There should then be no difficulty in mounting the capacitors on the switches.

S1 and S2 are 12 way single pole rotary switches having an adjustable end-stop. In this case, the end-stops are set for five way operation. The connections to the battery holder are made via an ordinary PP3 style battery clip.

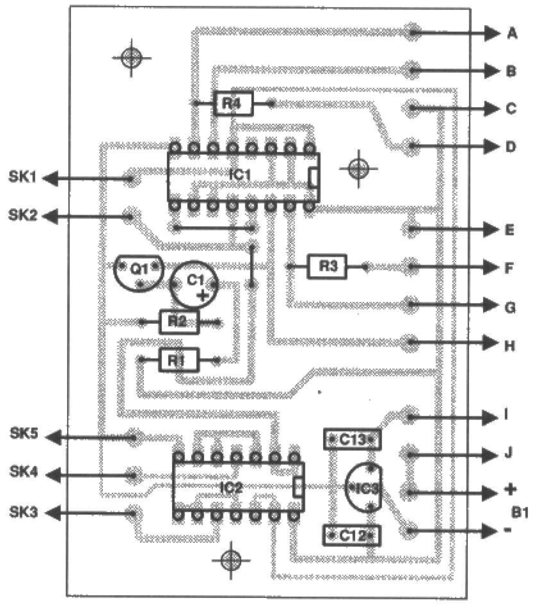


Fig. 3 PCB Component layout

Testing And Use

Ideally an oscilloscope should be used for testing the unit. It is then just a matter of checking that four main controls provide the correct output times and that all four outputs are providing proper signals. Bear in mind that the quoted times for each range are only approximate, and that the tolerances of the timing components will result in small but significant variations from one unit to another.

There will also be small discrepancies from one range to the next. Using 5% tolerance components for C2 to C11 keeps discrepancies within reason, but 1% capacitors must be used if a high degree of consistency is required. Bear in mind that the CMOS and TTL outputs operate at significantly different logic voltages. The CMOS outputs should provide signals at about 5V peak-to-peak. Expect the signals on the TTL outputs to be at a much lower level (probably no more than about 3V peak-to-peak).

If access to an oscilloscope is not available, monitoring the outputs with a crystal earphone will give a good idea of whether or not the unit is functioning correctly. A full range of audio tones should be available, plus low frequency clicks and buzzes with the controls set for mark and (or) space times. Short pulsed waveforms give a thin sound, while a mark-space ratio of about 1:1 gives a much fuller sound.

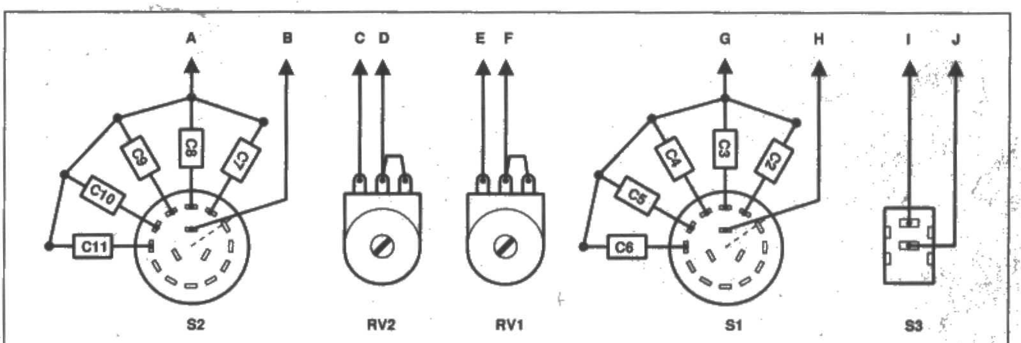
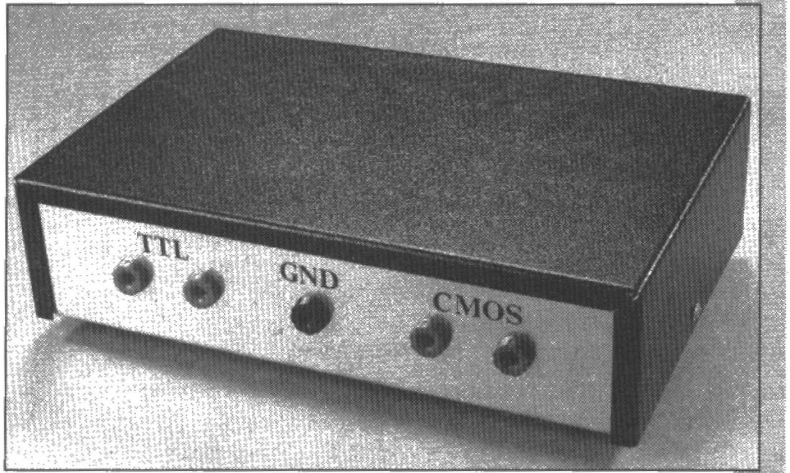


Fig. 4 Details of the hard wiring

With short mark and space times the output frequency will be beyond the upper limit of the audio range, and completely inaudible. A multimeter set to a low voltage range can be used to check the output at high frequencies. The multimeter will register to the average output voltage.

With a mark-space ratio of 1:1, the output voltage at the CMOS outputs should be half the supply voltage (2.5V). Higher mark-space ratios give higher voltage readings - lower mark-space ratios give lower voltage readings. For example, with a 1:10 mark-space ratio the output is high for only one eleventh of the time, so the average output voltage is only 0.45V (5 divided by 11 = 0.45). The not Q output is the complement of the Q output, and the mark-space ratio here would be 10:1. With this output high for ten elevenths of the time, this works out at an average potential of 4.54V (5V x 10 = 50 volts, 50 volts divided by 11 = 4.54 volts).

Due to a lack of symmetry at the TTL outputs the mathematics are less convenient. However, changes in the mark-space ratio should produce clear changes in the average output voltages. If the CMOS output signals are present and correct it is highly unlikely that there will be any problems with the TTL output signals.



If the unit is to be used alongside an oscilloscope, it is not really necessary to bother about calibrated scales around the control knobs of VR1 and VR2. Much better accuracy will be obtained by using the oscilloscope to monitor the output waveform and then setting the controls for the required mark and space durations. If calibrated scales are required, ideally an oscilloscope should be used to aid the location of precise calibration points. The only alternative is to use a guesstimated scale, but it is unlikely that this will give reasonable accuracy.

Note that the output of this unit should not be connected to a logic output in the test circuit. Where necessary, the integrated circuit providing an existing clock signal should be removed before the pulse generator is connected to the test circuit. Do not overlook the usefulness of the unit's low output frequencies. By operating the test circuit at a low frequency it is often possible to check its operation by using a logic probe or some LED indicators to monitor the logic levels at strategic points in the circuit.

If you are used to working in terms of pulse times and repetition frequencies, it is worth remembering that the reciprocal of the frequency in Hz, kHz, and MHz gives the duration of one cycle in seconds, milliseconds and microseconds respectively. For example, a frequency of 4kHz works out at 0.25ms per cycle (1 divided by 4kHz = 0.2ms).

PARTS LIST

RESISTORS (All 0.25W 5%)

R1	10k
R2	47k
R3	22k
R4	22k
RV1	220k lin carbon
RV2	220k lin carbon

CAPACITORS

C1	1µ 63V radial elect
C2	56p polystyrene 5%
C3	680p polystyrene 5%
C4	6n8 polystyrene 5%
C5	68n polyester 5%
C6	680n polyester 5%
C7	56p polystyrene 5%
C8	680p polystyrene 5%
C9	6n8 polyester 5%
C10	68n polyester 5%
C11	680n polyester 5%
C12	100n disc ceramic
C13	100n disc ceramic

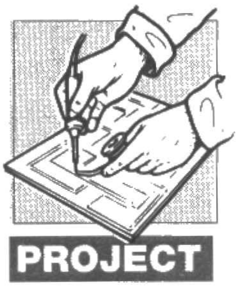
SEMICONDUCTORS

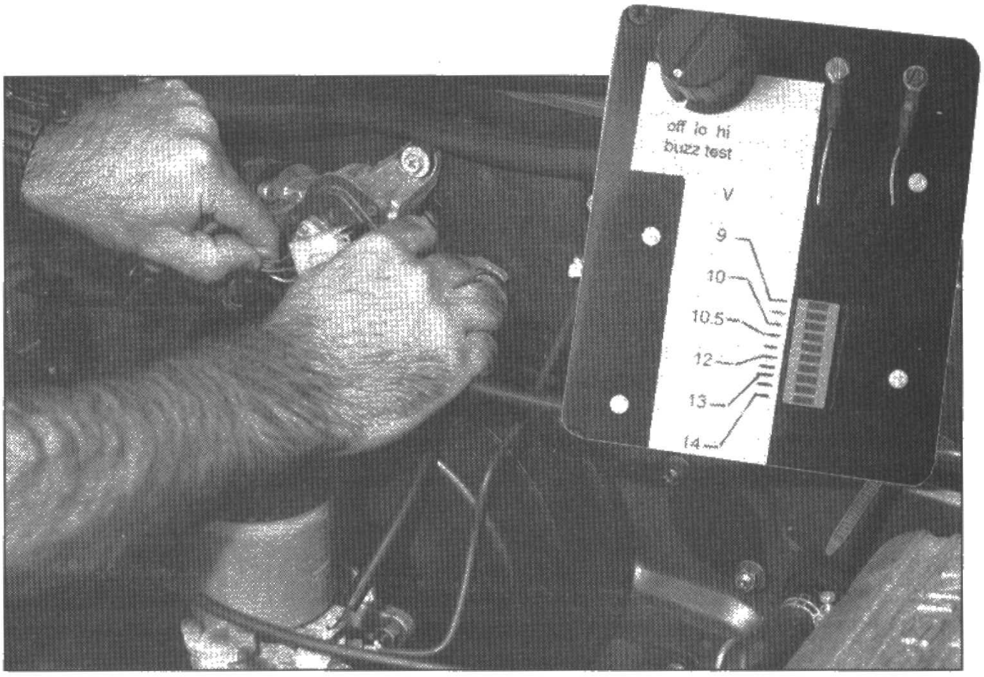
TR1	BC549
IC1	74LS221
IC2	4001BE
IC3	uA78L05 (5V 100mA positive regulator)

MISCELLANEOUS

S1	12 way 1 pole rotary (set for 5 way operation)
S2	12 way 1 pole rotary (set for 5 way operation)
S3	SPST miniature toggle
SK1 - SK5	4mm sockets (5 off)
B1	9V (6 x HP7 size cells in plastic holder)

PCB, instrument case about 200 x 130 x 50mm, battery connector (PP3 type), control knob (4 off), 14 pin DIL holder, 16 pin DIL holder, solder pins, wire, solder, etc.





Motor Mate

A handy aid for the car enthusiast, from Terry Balbirnie

The Motor Mate should prove to be a useful device for anyone who works on automotive type electrical systems. In this category we can include not only car owners, but also motorcycle, caravan and boating enthusiasts. The Motor Mate combines three functions - a voltmeter covering the range 9 to 14V, a low resistance, or continuity tester, which operates a buzzer when resistance is less than 10 ohms, and lastly a no continuity tester which sounds the buzzer when resistance is below 20K ohms.

The Motor Mate voltmeter gives the user a handy way of checking if battery voltage exists at fuses, switches, lampholders, etc. It can also be used to test for excessive voltage drops due to a wire being too thin, or as a result of loose connections, or corrosion. The low-resistance buzz-test may be used to test lamp filaments, fuses, motor windings, etc. and also to check lengths of wire where there is a suspected break. The high-resistance test is used chiefly for checking ignition leads and certain lamp filaments.

Motor Mate is built in a small plastic box, which houses the circuit panel and a 9V battery to power the buzz-test section. A pair of short wires on top connects a component for the buzz-test and a rotary switch is used to switch the unit off and on, as well as selecting the high or low resistance test. A pair of sockets on the side connects the voltmeter.

At the bar

The Motor Mate 'voltmeter' is not really a meter in the traditional sense. It takes the form of a bar graph display, which shows through a hole in the lid of the case. Thus, a row of ten horizontal LED bars light up one by one as the voltage applied to the input sockets increases. In the present circuit, these operate in approximately half-volt steps. Although the resolution and range are not good enough for general electronics use, this arrangement is adequate for most automotive purposes.

This type of meter is much more robust than a pointer-on-scale instrument and less expensive than a digital one. Also, the LED bars are easily seen in poor lighting conditions. The voltmeter draws approximately 30mA at 12V, so it cannot be

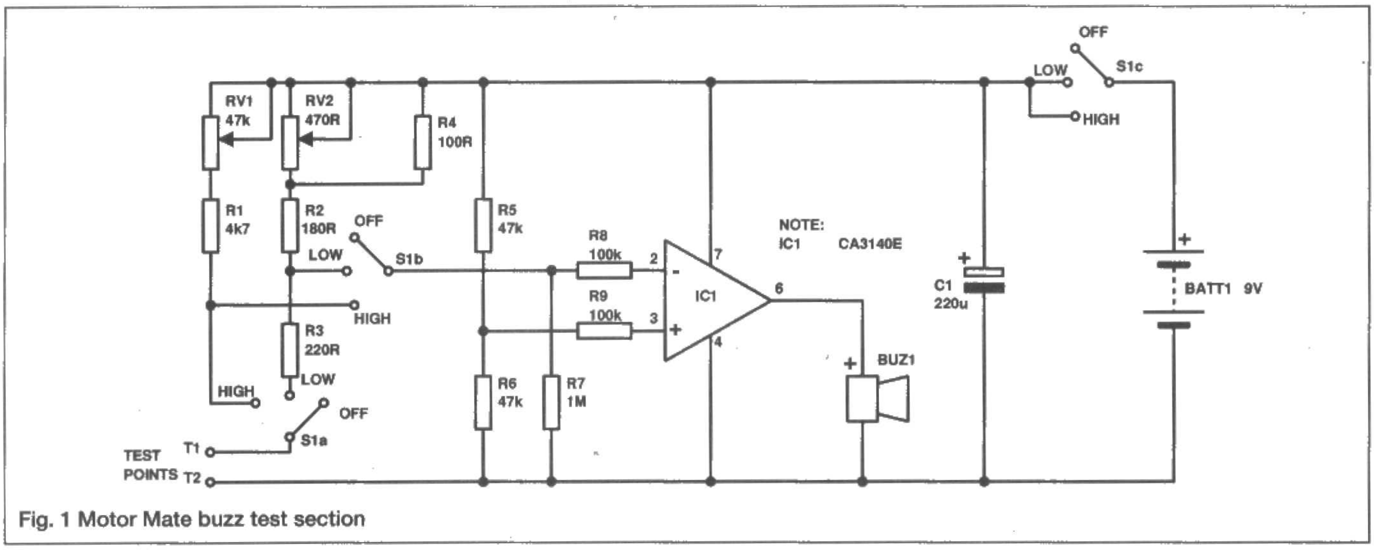


Fig. 1 Motor Mate buzz test section

described as a high resistance instrument by any means. However, for the present purpose, this does not matter and is usually an advantage because it imposes a load on the circuit. Sometimes fuses and corroded wires assume a very high resistance rather than a complete open circuit when they fail. A digital meter having an input resistance of some 10Mohms could therefore give a reading through such a high resistance which would be confusing.

My resistance is high

Car ignition leads carry current at a very high voltage from the ignition coil output to the electrodes in the distributor cap. A rotor arm then distributes the current to the appropriate lead, which is connected to the top terminal of the spark plug. Current completes the circuit back to the coil via the vehicle frame or chassis. The ignition leads are made with a high resistance to suppress TV and radio interference. This will have little effect on the current producing the spark, since the voltage supplied by the coil is very high (tens of thousands of volts).

Ignition leads are a common cause of engines misfiring and being difficult to start if their resistance becomes much higher than the nominal value, because this reduces the current. This may happen if they have been handled carelessly - possibly by pulling on them to remove the caps from the spark plugs - or it could be due to corrosion or simply through old age. The high resistance check can be used to identify faulty leads which may then be replaced singly, a much cheaper exercise than replacing them all at the same time.

As well as being suitable for automotive use, the buzz-test can be used around the house for checking fuses, switches, etc. Since the current requirement is only 20mA on the low resistance test under short-circuit conditions (the worst case), and only 1.6mA while switched on but not actually in use, the battery will have a long life.

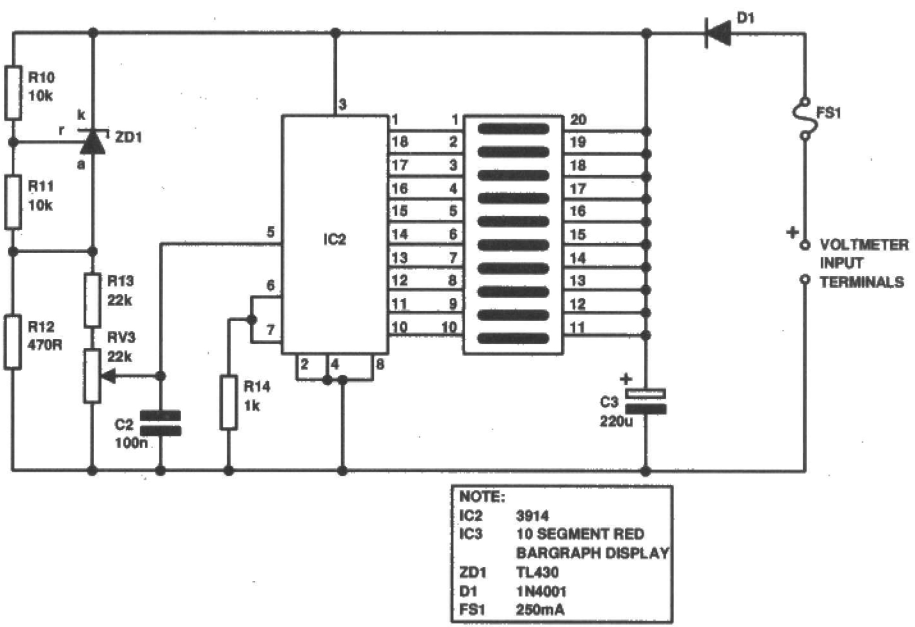


Fig. 2 Motor Mate voltmeter section

The two sections of the circuit - voltmeter and buzz-tests - are described separately. To avoid confusion, components are numbered sequentially, beginning in the buzz-test section and continuing in the voltmeter. It is not necessary to understand how Motor Mate works in order to construct it and readers who wish to go on to Construction may simply omit the next section.

Circuit description

The buzz-test section of Motor Mate is shown in Figure 1. The chief component is IC1, an operational amplifier which is used as a voltage comparator. Thus, If the voltage applied to its inverting input (pin 2) exceeds that at the non-inverting one (pin 3), the output (pin 6) will be low. If the inverting input voltage is less than the non-inverting one, pin 6 will be high and buzzer, BUZ1, will sound.

Pin 3 is maintained at one-half supply voltage by the potential divider, consisting of equal-value resistors R5 and R6. The various other resistors to the left of this form further potential dividers - one set for the low resistance test and another for the high one, as selected by switch S1. The conditions for the op-amp to switch on and hence the buzzer to sound is met when the resistance of the lower arm is less than that of the upper one.

Switch S1 is a 4-pole 3-position switch. In this circuit, only three of the poles are used, these being referred to in the text and diagrams as S1a, b and c. Poles a and b are responsible for the switching between high and low buzz-tests and pole c simply provides an on-off function.

Suppose S1 is set to high. S1 pole b connects IC1 inverting input via R8 to the potential divider, consisting of preset potentiometer RV1 with fixed resistor R1 in series as the upper arm. The component under test is connected via S1 pole a to test points T1 and T2, this forming the lower arm of the potential divider. Suppose RV1 wiping contact is set to approximately mid-track position. The total resistance of the upper arm will be around 25kW. The buzzer will therefore sound if the test component has a resistance less than this figure. By suitable adjustment of RV1, the threshold resistance may be set anywhere between 5kW and 50kW approximately.

A similar situation occurs with S1 set to low, but now S1b connects RV2 in parallel with R4 and R2 in series in the upper arm. The lower arm consists of fixed resistor R3 in series with the component under test. The purpose of fixed resistors R2 and R3 is to limit the current flowing in the potential divider and so prevent excessive drain on the battery. The purpose of R4 is to effectively reduce the value of RV2, since very low preset values are not available from all suppliers. Adjustment to RV2 will allow operation of the low-resistance buzz-test at any point below approximately 50W.

The voltmeter section of Motor Mate is shown in Figure 2. Current is supplied via fuse F1 from the car battery powering the circuit under test and connected to the input terminals.

The circuit centres on bar graph driver IC2 and the bar graph display itself, IC3. IC2 is a complex device containing a set of ten voltage comparators. When the voltage applied to the input, pin 5, is increased, the comparators operate one by one and the outputs, pin 1 then 18 to 10, go low in turn. Current then flows from the supply though the appropriate light-emitting diode bar in IC3 to sink into the corresponding IC2 output.

As it stands, the first bar would light when the voltage at pin 5 reached 0.125V and successive ones with each further

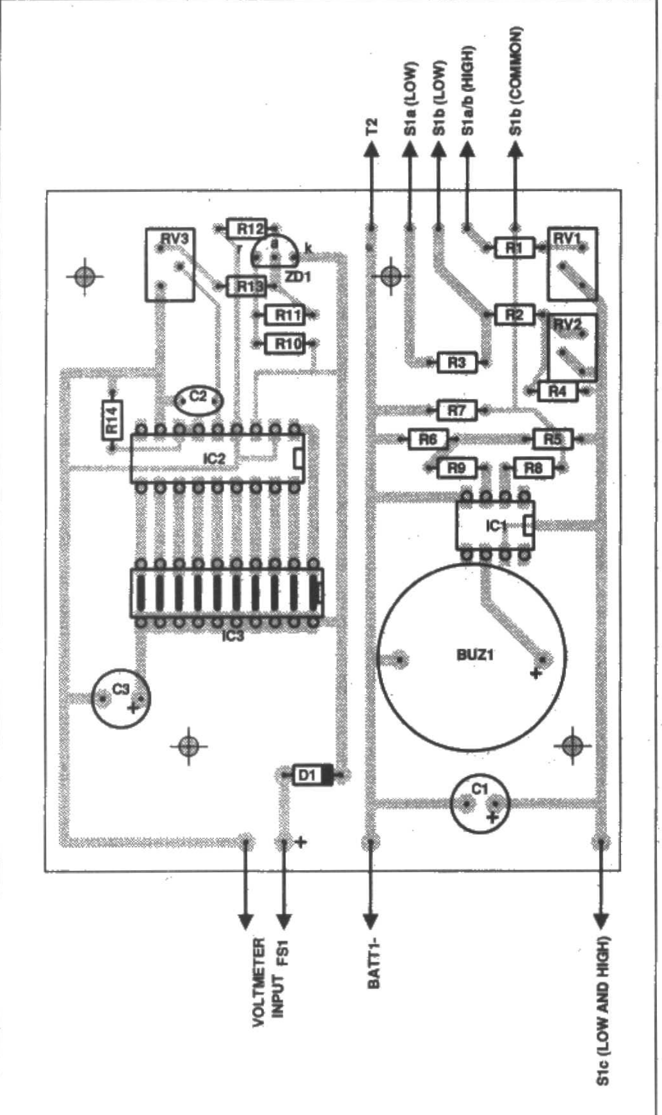


Fig. 3 PCB component layout

0.125V. Thus, the second bar would light at 0.25V, the next at 0.375V and so on. The tenth one would therefore operate at 1.25V. Since the required range of voltage is from about 9V to 14V, this would make IC1 as it stands unsuitable for the purpose.

The behaviour is modified by using ZD1 and associated components. ZD1 is an adjustable Zener diode. Not only is its performance superior to an ordinary Zener diode but its breakdown voltage can be accurately set by connecting two external resistors, R10 and R11, to the reference (r) pin as shown. With the values used here, the breakdown voltage is 7.7V approximately. For readers wishing to alter the voltage, perhaps to use the voltmeter for some other purpose or to set the low operating point more accurately, the formula giving the output voltage is:-

$V = 2.75(1 + R10/R11)$

This voltage will then exist between ZD1 anode (a) and cathode (k) as long as the supply exceeds this. ZD1 operates in conjunction with series resistor, R12. Since there is a constant voltage across the Zener diode, the balance of the supply voltage will exist across R12 and it is this which is monitored by the rest of the circuit. Taking into account the 0.7V, approximately, which exists across input diode D1, zero volts will exist across R12 with an applied voltage of about 8.4V and the first segment of the display will light about 0.5V higher than this - i.e. at about 9V, which is convenient for the purpose.

It is necessary for the bars to light up in approximately 0.5V increments. This means that the existing 0.125V steps must be scaled by a factor of four. This is the purpose of preset potentiometer RV3 and fixed resistor R13. By adjustment to RV3, a certain fraction of the voltage appearing across R12 is applied to IC1 pin 5. R13 limits the range of adjustment.

Construction

Construction of Motor Mate is based on a single-sided PCB. Figure 3a shows topside details (parts placement diagram) while Figure 3b shows the underside (copper foil) view. Both sections - voltmeter and buzz-test - are separately formed on the one panel.

Prepare the board by drilling the four mounting holes in the positions shown. Add the soldered components in the following order. Firstly, the IC sockets, then the presets and all resistors and capacitors, taking care over the polarity of C1 and C3. Solder ZD1 into position (see pin diagram) and diode D1, but do not insert the ICs into their sockets yet. Add the buzzer observing the polarity - this is marked on the plastic underside. Solder 15cm pieces of stranded connecting wire to the labelled pads in the diagram but not to the one marked BATT1. Using different colours of wire will help in avoiding errors which may be difficult to track down later.

Solder the negative wire of the PP3 battery connector to the pad marked BATT1. Adjust all presets to approximately mid-track position. Finally, insert the ICs, observing the orientation. Note that IC1 and IC2 are CMOS devices and possibly liable to damage by static charge which may exist on the body. To avoid problems, do not touch the pins when unpacking them or inserting them into their holders. Alternatively, touch something earthed - such as a water tap - just before doing so. IC3 may be handled freely. Unfortunately, its orientation is not obvious and it will not work if connected the wrong way round. In the prototype unit the identifying lettering was on the right-hand side of the body.

The circuit panel is attached to the lid as shown in the photograph. Carefully measure the position of the bar graph display

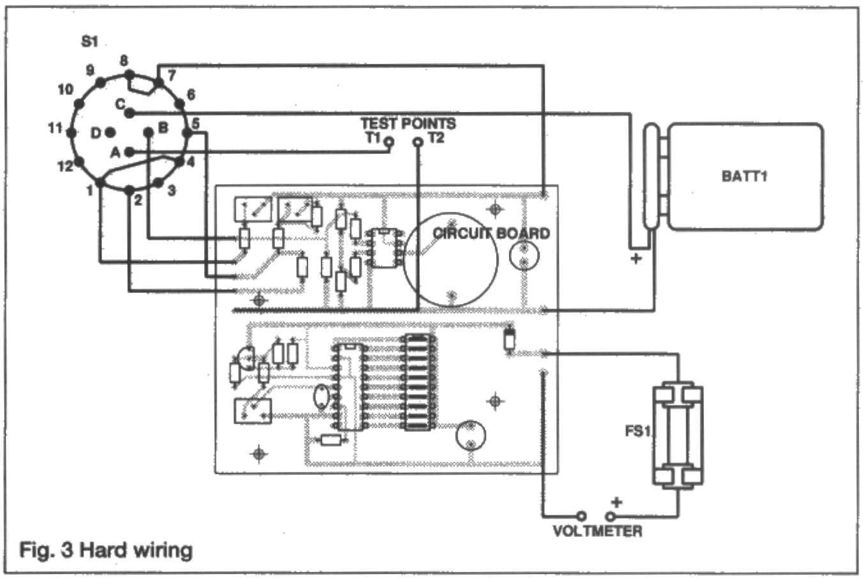


Fig. 3 Hard wiring

and the mounting holes, and mark them on the lid. Make the holes for these and, using thin nylon bolts, mount the circuit panel temporarily in position. In the prototype unit it was found that no spacers were needed on the bolt shanks because the presets and capacitors on the board provided the right amount of clearance so that the face of the display ended flush with the case. However, use some plastic spacers if necessary. Remove the circuit panel again - this is necessary so that the other holes may be drilled safely and also to enable adjustments to the presets to be made later

Drill the hole in the lid for rotary switch S1 and for the small bolts which will be used for the buzz-test wires - more will be said about this later. Drill two holes in the side of the box for the 4mm voltmeter sockets. Drill the holes in the side for fuse holder F1 and in the base for the PP3 battery holder. Drill a few small holes above BUZ1 position for the sound to pass through. Mount all components but not the circuit panel and, referring to Figure 4, and complete all internal connections shortening any wires as necessary. Note that S1 is shown disproportionately large for clarity. The numbers and letters are conventional and found inscribed on most switches of this type. On completion, the use of small cable ties will tidy up the wiring by grouping it into neat bundles.

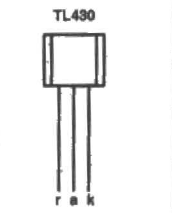


Fig. 5 PIN diagram of ZD1 looking at flat of body

In the prototype unit, the buzz-test connections were made using two small nuts and bolts, each with a solder tag inside and outside the box. The external solder tags are used to connect short test leads. This method has the advantage that the leads can be bent to make contact with a wide variety of lamps, fuses, etc. Also, they are easily replaced when they eventually break. In the prototype, 22 swg tinned copper wire was used, but cut-off pieces of paper clip or resistor ends would probably serve just as well. A length of one inch (25mm) will be found convenient. A little heat-shrinkable sleeving used on the soldered ends is cosmetic, but makes the device look more professional.

Adjustments

The best way to set up the 'voltmeter' is to use a variable voltage power supply unit and a conventional voltmeter. If this equipment is not available, you will have to make do with a 12V battery - say a 9V battery connected in series with two 1.5V cells. In the absence of a voltmeter, you will have to assume that the batteries have their nominal voltage. Make up a pair of leads for the voltmeter terminals. These will have 4mm plugs on one end and possibly small crocodile clips on the other. It would also be possible to use standard 4 mm test meter probes. To some extent, the design and length will depend on the anticipated use.

If a variable output mains-operated power supply is being used, connect it to the voltmeter sockets, observing the polarity. Begin at zero and gradually increase the voltage. The first bar of the display should light at about 9V. Continue to increase the voltage and note that the segments light one by one. Adjust RV3 so that the last one comes on at 14V. Do not exceed 15V at any time. Note that there is a slight overlap built into IC2 operation so it is possible for two bars to light at the same time.

If you are using a 12V battery, connect it to the voltmeter terminals and adjust RV3 so that the 6th or 7th segment lights up. If the true voltage can be checked with a voltmeter so much the better. Note that when RV3 is adjusted for the required high point, this will alter the low point slightly. However, there should be no problem in adjusting it to a suitable compromise position. At this stage it would be a good idea to make a rough voltage scale. Do not aim for high accuracy here - the prototype covered 9 - 14V in a slightly non-linear way.

Buzz tests

Connect BATT1 and switch S1 to low. Hold the 10W test resistor onto the test points and adjust RV2 until the buzzer sounds. It could be arranged to operate at any resistance below about 50W by using the appropriate test resistor.

The high resistance buzz-test is similarly adjusted using, say, a 22kW resistor in the test position. Set S1 to high and adjust RV1 until the buzzer sounds. The resistance of most car ignition leads is around 5kW per foot (30cm) of length and adjustment to 20 - 30kW will be found to work well in practice.

It only remains to fit the circuit panel into position and make permanent labels for the voltmeter scale and switch. Fit the lid, checking carefully for trapped wires. Stick plastic feet on the bottom of the case if necessary. Note that very low-power 12V bulb filaments and most mains lamps have a cold resistance higher than 10W. When checking such lamps use the high-resistance buzz- test. Remember, after using the buzz-test, to switch the unit off or the battery will soon be drained.

PARTS LIST

RESISTORS

R1	4k7
R2	180R
R3	220R
R4	100R
R5,6	47k
R7	1M
R8,9	100k
R10	18k
R11	10k
R12	470R
R13	22k
R14	1k
RV1	47k
RV2	470R
RV3	22k

Additional 10W and 22kW resistors required for testing purposes - see text.

CAPACITORS

C1,3	220µF 16VW
C2	100n

SEMICONDUCTORS

D1	1N4001
ZD1	TL430 adjustable Zener diode
IC1	CA3140E
IC2	LM3914 bar graph driver
IC3	10 segment red bar graph display

MISCELLANEOUS

S1	3-position 4-pole rotary switch break-before-make action.
BUZ1	PCB mounting solid-state buzzer 3 - 24V operation. 23mm diameter
F1	250mA 20mm fuse and chassis fuseholder
BATT1	PP3 battery, connector and holder
Plastic box	118 x 98 x 48 mm external

8-pin dil socket, 18-pin dil socket, 20 pin dil socket.
4mm sockets
Solder tags - 4 off.
Small nuts and bolts.

Lets go fishing

Andrew Armstrong helps solve an ETI reader's fishy problem

We had an interesting query recently from an ETI reader in Germany. The reader, Andrew Mathison of Echzell-Bisses, is interested in angling as well as in electronics, and would like to build a fish-bite detector. He owns one at present, which he thinks is too costly, so instead of buying a second one, he wants to build one for himself.

His present detector uses an idler-wheel with magnets fitted around it close to the rim, as shown in Figure 1. A reed switch is mounted so that the magnets can activate it as they pass. Because a number of magnets are fitted to the wheel, only a small movement of the fishing line is needed to make the reed switch operate. The magnets need to be light and numerous for the best performance.

He goes on to say that his commercial bite detector uses a 4538 chip and that, when a bite is detected, there is a 0.5 second bleep generated by a Piezo sounder. A light-emitting diode is switched on for between 10 and 15 seconds, as well, in order to show which detector (if several are in use) has detected a bite.

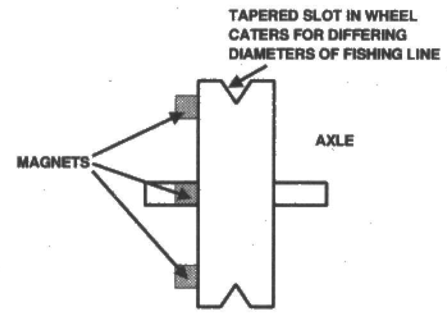

TAPERED SLOT IN WHEEL CATERS FOR DIFFERING DIAMETERS OF FISHING LINE
AXLE
MAGNETS

Fig. 1: Sensor wheel

Not one to leave anything to chance, Andrew wishes to add a further refinement: the ability to choose the frequency of the tone, so as to identify which bite detector has operated audibly, as well as visually.

According to my data book, the 4538 is a dual-precision CMOS monostable, which would seem the obvious chip to use for this kind of job. It can be triggered either by a negative-going clock edge on the B input, or a positive-going edge on the A input. There is no upper limit on the output time duration, except that imposed by practical capacitor and resistor values, so a 10 second time period is easily obtainable.

Figure 2 shows a suitable design employing the 4538. No on-off switch is shown in this design, because the quiescent current consumption is so low that the switch is unnecessary. The circuit is shown as being powered from a 5V supply, but this type of CMOS chip will work over a voltage range of 3 to 18V, so in practice a set of four AA-size batteries in series will form a suitable power supply, giving 6V when the batteries are new.

When the wheel turns and the reed switch closes, both monostables are triggered. The first monostable has a time-constant, given by R2 and C2, of 10.34 seconds. One of the design features of the 4538 is that its output time period is equal to the RC time constant.

The LED is driven directly by the output of the first monostable, with a current-limiting resistor to save components. A low-current LED, which gives a good brightness with a current of around 3 mA, should be used. The Hewlett-Packard HLMPK 150 is particularly suitable for this job. If this is not bright enough, or if a low-current LED is not available, then a small mosfet should be used to drive a higher-current LED. One example of a suitable mosfet would be the VN10.

The second monostable has a time-constant of 470 milliseconds and its output drives one of the gate inputs of a conventional CMOS oscillator. The frequency of this oscillator may conveniently be chosen by selecting a suitable value for R6, the approximate output frequency being given by 1/(2.2*R*C). The output from the oscillator is fed via a capacitor with a bleed resistor to 0V, to avoid applying DC to the Piezo-electric sounder. Most Piezo-electric sounders have a specific resonant frequency and the oscillator frequency should be chosen to match this. Maplin stocks transducers, resonant at 1.8 kHz, 2.8 kHz and 4.2 kHz, as well as stocking one which can operate, though with lower efficiency, over the range 750 Hz to 20 kHz. This particular range of sounders is not encased, and should be mounted on a suitable surface to act as a sounding board.

An alternative sounder output is provided in case a higher volume is required, or for use on lower voltages. This operates symmetrically, so DC blocking is not required. The apparently complicated gating arrangement is used to lock the output to logic 0 rather than logic 1, when the sounder is not activated, to avoid placing a continuous DC voltage across it.

This fish-bite detector will cost a lot less than the £40-£100 which they apparently cost in Germany. It does use high impedances, in order to keep current consumption low and to allow practical-sized timing capacitors, so care must be taken to house it so that water ingress is prevented. Because it is to be used beside a river and could be dropped into the water, it is probably best to encapsulate the circuit board once everything is working. In my experience, some epoxy encapsulants can slowly absorb water, interfering with the operation of high impedance circuitry. I therefore recommend a two-part silicone rubber encapsulant or, if this is not obtainable, a thick layer of spray-on conformal coating.

This is a simple unit which should present few problems and, to my mind, the only difficult part is the mechanical bit. Do remember, however, that in order to obtain good reliability and low current consumption, anti-static handling procedures must be observed with the CMOS chip. As I have discovered, CMOS has a static damage mode in which quiescent current consumption is increased, but the chip works, perhaps for months, before failing.

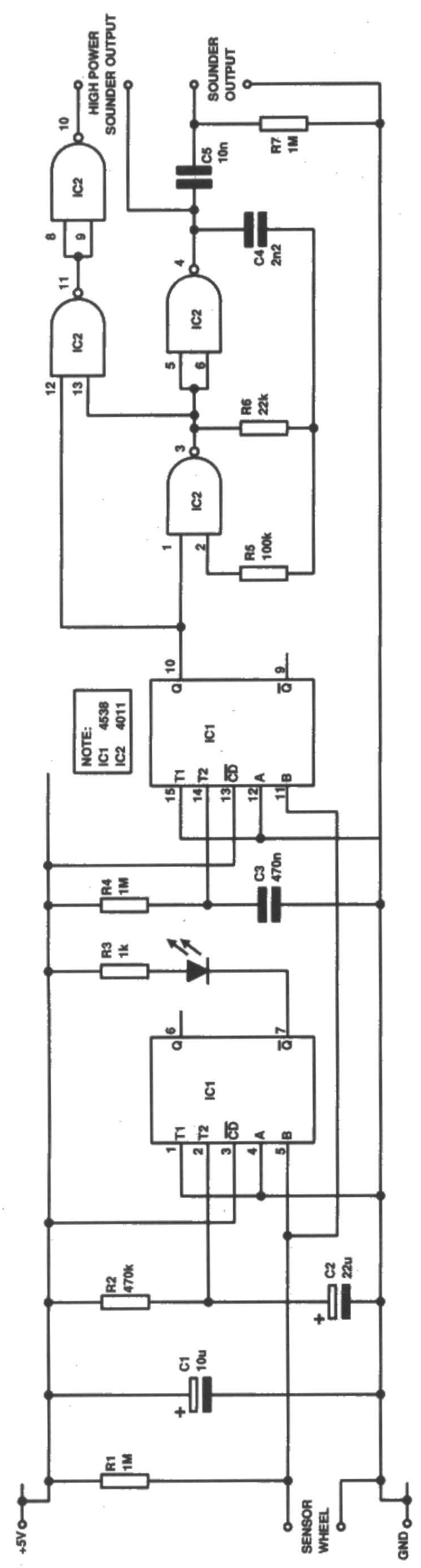


Fig. 2: Circuit diagram

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Microprocessor Fundamentals

Part 2

Last month we looked at some of the control circuitry needed to implement a simple microprocessor system. In this issue we are looking at the main data and address buses, and how memory is mapped

Most simple eight bit microprocessors, such as the 6502 and the Z-80, have sixteen address lines and eight data lines, the so called address and data buses. The processor uses the address lines to select memory locations, and with a binary output on sixteen address lines it can select any one of up to 216 or 65,536 unique memory locations. Once a memory location has been selected, data can be read from it, or written to it, using the eight bit wide data bus.

These memory locations could be read only memory, ROM, or read/write memory, RAM, the type of memory depending on whether it is used for the permanent storage of a program or the temporary storage of data or program code. I have used the word memory location, but such a location does not have to be within a memory chip, it could equally well be a register or an input/output port, a register being a memory location that is used to transfer data between the processor and some other circuit, and an I/O port being a means of allowing the processor to communicate with external devices, such as keyboards, etc. To the processor, registers and I/O ports look and behave exactly like ordinary memory locations.

The memory map

The sixteen address lines of a common 8 bit microprocessor allow us to access 65,536 memory locations. This is referred to as the processor's address space. Some processors, like the 6502 have just a single address space in which all memory and input/output registers are located, while other processors like the Intel 8080 family separate the address space for memory from the address space for I/O, a feature which allows such processors to have special I/O instructions.

If we are using a processor in which ordinary memory and I/O reside within the same address space, then we need to define certain areas of the address space for I/O ports, other areas for ROM memory and other areas for RAM memory. This mapping out of specific areas for specific functions within the overall processor address space is referred to as the memory map and its creation is one of the primary tasks in designing any processor based system. A memory map is equally important in systems where there is a separate memory address space and an I/O address space, it is simply a little more complex.

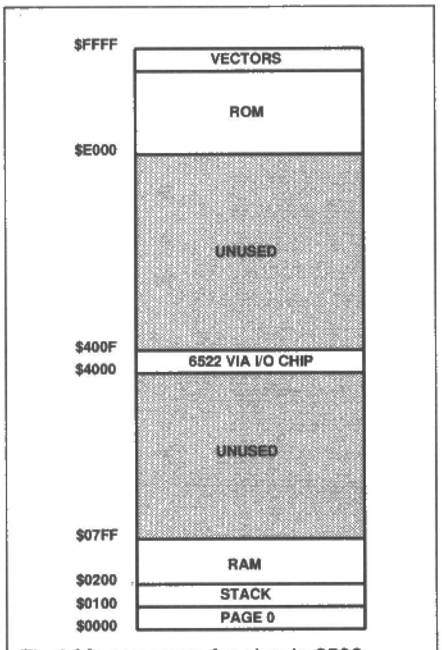


Fig.1 Memory map for simple 6502 based system

Every system will have to have some code resident on ROM, as without such code it, would be virtually impossible to load a program into RAM memory and then run it. This minimal code is often referred to as the kernel and has the function of initialising the processor registers and any I/O registers. The kernel program will then either jump to the main program, which is also stored in ROM, or will attempt to get data from an external device, such as a keyboard or a serial port. Data which it will store in RAM and which may constitute the code for the main program.

Whereas all systems will have some ROM memory, it is possible for a system to function with no RAM memory. Indeed, many control applications can get by with simply using the processor's internal registers for data storage. As far as I/O is concerned, a system could function perfectly well without data input from, or output to, the external world, but such a system would be somewhat pointless since it would not do anything. All practical systems will, therefore, have some memory locations dedicated to use by I/O registers.

When the processor powers up, or is reset, it automatically sets the program counter to a memory address which is stored in a specific location in memory, called the Reset Vector. This is the starting address of the kernel program. It is one of a number of vectors and others specify starting addresses of routines which handle hardware interrupts, etc. All these vector addresses are stored in ROM memory.

The memory address which is stored in the Reset Vector, is the starting address of the kernel program, also stored in ROM memory, and it thus makes sense to reserve memory locations around the vector addresses (usually the top half a dozen memory locations in the memory map) for ROM memory. A common memory map

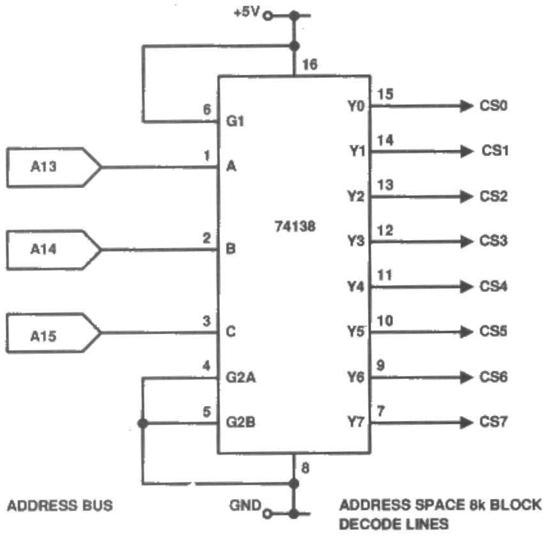


Fig.2 8K Block decode circuit

arrangement is to allocate the top 8 or 16Kb of address space to ROM memory.

As far as RAM memory is concerned, the system may not need any. However, if RAM memory is needed then, it is best located at the bottom of the memory address space. This is because many processors make use of a series of read/write memory locations called a stack and most of them locate this stack in the bottom part of memory. The stack is a special area of memory used to put temporary variables and has its own special processor register, the stack pointer. The stack makes programming a lot easier and allows us to use subroutines.

All we are now left with is the location of the I/O registers. These can be placed anywhere in the unused address space beneath the area allocated to ROM memory and above the area allocated to RAM memory. When choosing the location of I/O registers, it is wise to use memory locations which start at one that is easily decoded, such as location 4000hex. Many I/O devices will use several registers, but it is only the first register which needs to be decoded.

So, if we are designing a simple microprocessor system, we can now lay out a memory map. The proposed system is based on the 6502 and it has 8Kb of ROM memory, 2Kb of RAM memory and a single 6522 VIA chip for I/O. This uses sixteen memory locations starting at location 4000hex, and the memory map for this system is shown in Figure 1. More complex designs will, of course, have more complex memory maps.

Address decoding

Armed with the memory map, a system designer can now turn to the decoding circuitry which will ensure that the address bus will access the correct type of memory at the locations designated on the memory map.

For the simple design outlined above, we have three components which need to be attached to the address and data bus, a ROM chip (probably an EPROM), a RAM chip and the 6522VIA I/O chip. For the ROM chip, we could use a 2764 EPROM which is organised as 8K x 8 bit words, and for the RAM memory a 6116 static RAM which is organised as 2K x 8 bit words. In simple designs, static RAM is preferable to dynamic RAM, since it requires no refresh circuitry.

On all three chips, the data lines are connected directly to the data bus and the address lines to the corresponding lines on the address bus. In the case of the ROM chip, A0-A12, for the RAM chip, A0-A9 and for the VIA, A0-A3. If they were left like this, then each of the three chips would occupy memory locations that overlapped in the address space with that occupied by the other two. The result would be a chaotic system full of erroneous data.

We need to separate the three memory chips so that each occupies its own unique portion of the address space and, to do this, we need an address decoding circuit. For a simple system like this, we can use an address decoding circuit which divides the memory address space into eight 8K blocks. Then we can put our ROM into the top 8K block, the RAM into the bottom and the I/O into the third block up from the bottom.

We can do this address decoding by using the top three address lines from the processor, A13-A15, and feeding them into a decoder chip, such as a 74138. The eight outputs from this decoder chip can then be used to generate the appropriate chip select for our three memory and I/O chips. This decoding circuit is shown in Figure 2.

We can see how this circuit allocates blocks of the memory address space, in the memory map used in Figure 1, to the different components in table A.

The unused chip selects could be used to add extra ROM, RAM or I/O to the system. By and large, decoding the memory space into 8Kb blocks should be adequate for most applications, but where a lot of I/O is used, it may be

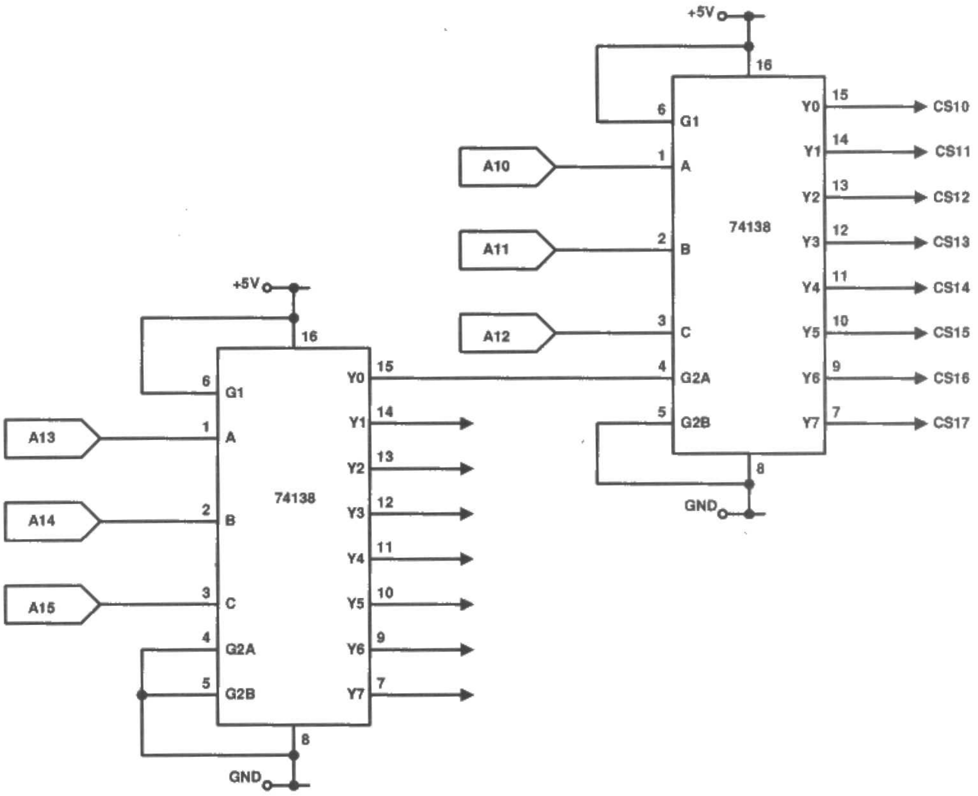


Fig.3 Cascaded decoding to 1K blocks

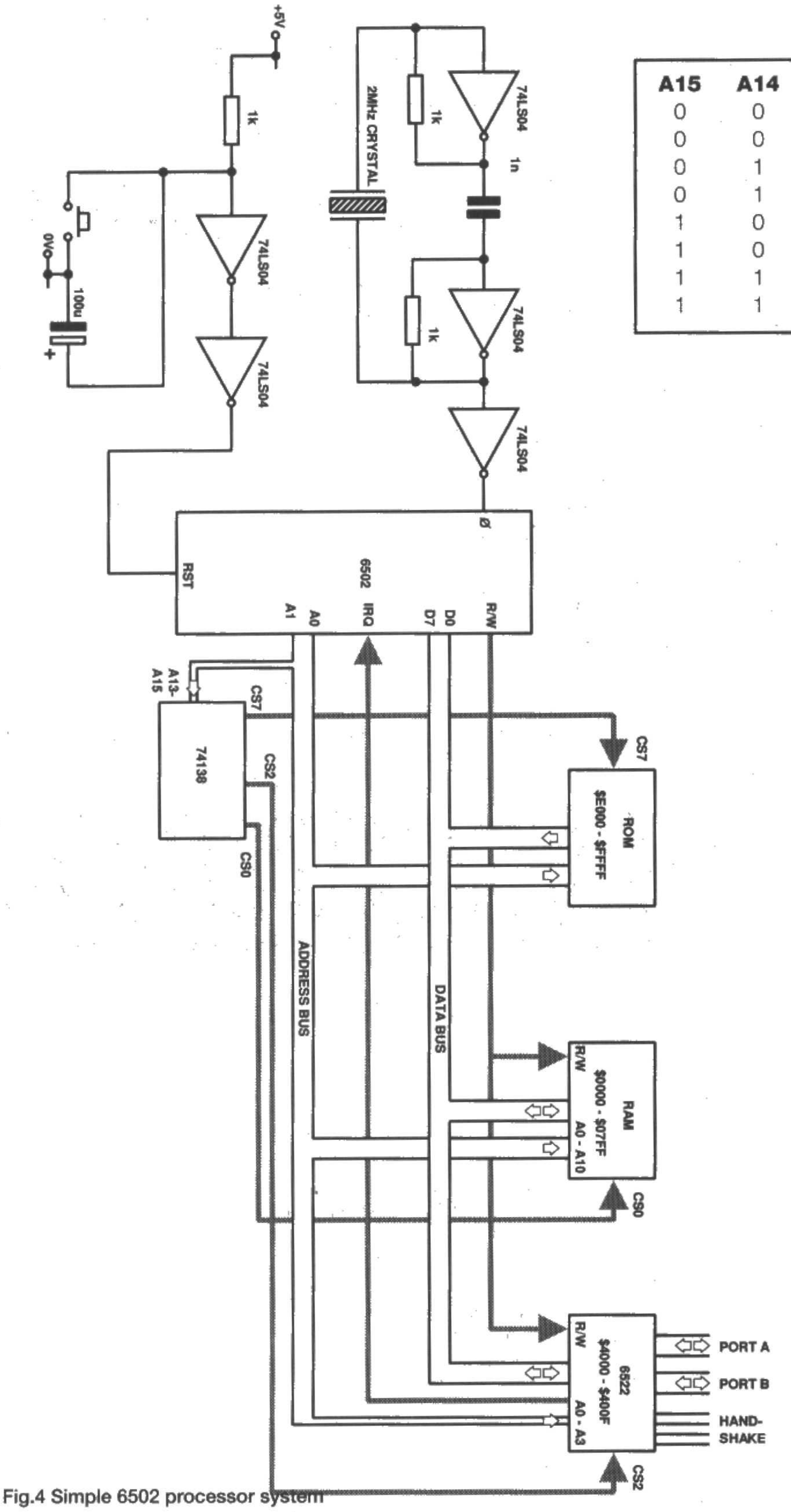


Fig.4 Simple 6502 processor system

Table A

A15	A14	A13	Addresses	Select line	Use
0	0	0	$0000-$1FFF	CS0	RAM
0	0	1	$2000-$3FFF	CS1	
0	1	0	$4000-$5FFF	CS2	I/O
0	1	1	$6000-$7FFF	CS3	
1	0	0	$8000-$9FFF	CS4	
1	0	1	$A000-$BFFF	CS5	
1	1	0	$C000-$DFFF	CS6	
1	1	1	$E000-$FFFF	CS7	ROM

necessary to further decode a single block. This is simply done with the aid of another 74138, as shown in Figure 3, which breaks one of the 8K address space blocks into eight 1Kb blocks.

Putting it all together

Using the memory map in Figure 1, we have now developed a very simple processor design using the 6502. The system has 8K of ROM, 2K of RAM, two 8 bit bi-directional I/O ports, a 16 bit timer and a serial I/O line. A system which is adequate for a wide range of control functions, and as the basis for many projects.

However, we first of all need to bring all the bits of the design together. The first things to look at are the two control lines from the processor, R/W and IRQ(or NMI). The R/W line determines whether the memory location specified on the address bus is being read by the processor, or written to by the processor. For ROM memory, this line is not needed since one can only read it, but for both RAM and I/O it is essential and should be connected to the appropriate line.

The IRQ and NMI lines are used by I/O circuitry to generate processor interrupts. The difference between the two is that software can be used to disable the IRQ interrupt, but an NMI interrupt will take priority over all other operations, including an IRQ interrupt. When either of these interrupt signals is generated, the processor will halt its current operation, and jump to a piece of code, which has a beginning address specified in the appropriate vector at the top of the memory address space. One of these two interrupt control lines should be connected to the appropriate interrupt output from the I/O chip.

We now have all the components connected together for a simple microprocessor system, shown in Figure 4. Larger systems will, of course, be a lot more complex. Thus, for example, if a lot of ICs are connected to the data and address buses, it may well be necessary to incorporate bus drivers in the design to increase the drive capability of the bus lines. Other types of I/O will bring with them their own complexity. However, the fundamental design of any microprocessor system is the same and will vary but little from that in Figure 4.

Alex Stewart

Next month

We will be looking at the basic control software for this simple system and taking a further look at I/O circuitry. Elsewhere in ETI, we will be including a project to build an ultra small Z-80 processor, ideal for incorporating into a wide range of projects.

Bicycle Alarm

Don't let your bike be stolen - fit Alan Bradley's compact alarm unit.

PROJECT

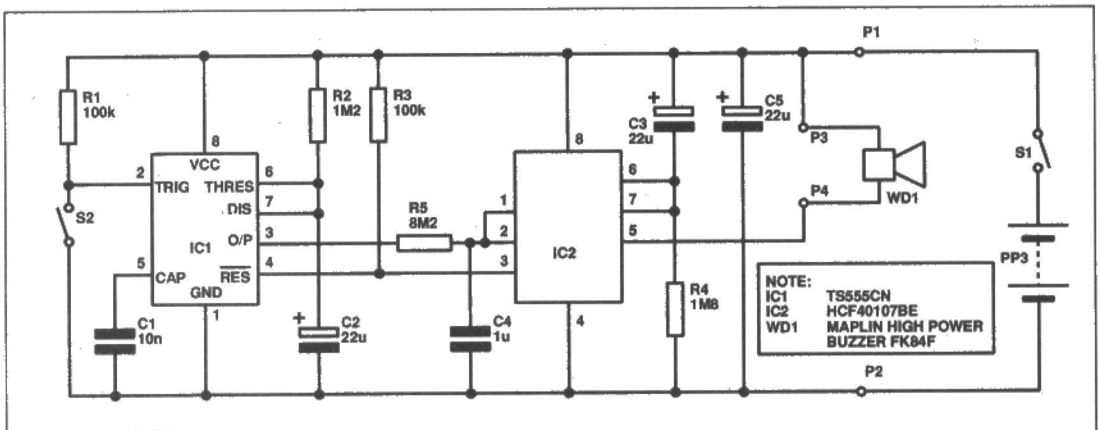
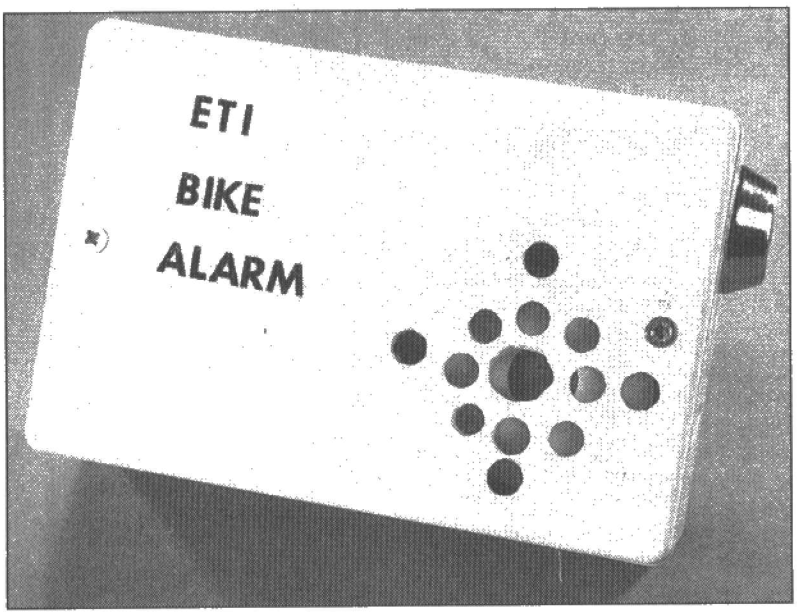


Fig.1: Circuit Diagram

Bicycles are an easy target for any thief, and cyclists find themselves increasingly encumbered with chains and padlocks to try and counter this constant threat. But even chaining your bicycle to a lamppost or some railings may not be enough to deter the skilful thief armed with a few tools. He may not steal the whole bike, but he might steal parts of it!



One obvious solution to the problem is to fit your bicycle with an electronic alarm unit which will be triggered whenever the bicycle is moved. With an alarm fitted, anyone trying to tamper with the bike will almost certainly trigger an audible alarm. Enough to frighten them, and send them looking for an easier target.

The cycle alarm described in this project is small, light and compact. It is operated by a key and is small enough to hide in a pannier or saddle-bag pocket.

The alarm system

The alarm in this design is armed and disarmed by a key operated on-off switch. Any vibration due to a would be thief attempting to break the lock or carry the bike to a van will, after a short delay, cause the sounder to operate for approximately 25 seconds. The alarm will then re-arm, ready to be triggered again. Continuous vibration will operate the alarm continuously.

Immediately after the alarm has been switched on there is a 'turn-on' delay of about 21 seconds, before it will respond to vibration to allow the owner time to remove the key and close the pocket.

A turn-off delay has also been provided. The sounder will not operate for approximately 7 seconds after a detected vibration to allow the owner time to disarm the alarm.

The alarm has a low quiescent current of 135µA and only uses 15mA when the sounder is operating. The alkaline PP3 battery should therefore have a very long life.

How it works

The heart of the circuit is IC1, a TS555CN CMOS low power timer IC configured as a monostable.

When in the armed state, IC1's trigger input is normally held high by resistor R1. When the alarm is knocked, the vibration detector (S2) will close, pulling IC1's trigger input low. The output of IC1 (pin 3) now goes high for a period of 1.1R2C2 (32 seconds in this case).

The output of IC1 is followed by the R5C4 delay circuit. This provides approximately a 7 second delay, before the sounder operates. IC2 is an HCF40107BE CMOS dual NAND gate with 'open drain' outputs. It is used as a high input impedance buffer following the turn-on and turn-off CR delays.

Reset (Turn-on) CR Delay and Buffer

One half of IC2 is used as an inverting buffer between the C3R4 turn-on delay and IC1's Reset pin. The CMOS buffer will change state at approximately 1/2Vcc, as opposed to the TS555CN's Reset pin which views 0.7V and above as High. The use of the buffer therefore requires a smaller C3R4 product and allows the use of a smaller and cheaper capacitor. R3 is a pull up resistor for the buffer's open drain output stage. This inverting buffer and C3R4 delay holds IC1's Reset pin (and hence its output pin) low for approximately 21 seconds after the alarm is switched on.

Sounder (Turn-off) CR delay and buffer

The other half of IC2 is used as a non inverting buffer. Its MOSFET output transistor can sink 32mA at 5V and 74mA at 10V, so can therefore be used as a follower to drive the sounder.

WD1 is a high output Piezo sounder with built-in drive circuitry. At 9V it uses approximately 15mA. C5 is a power supply decoupling capacitor.

Calculating the buffered CR Delays

Assuming the buffer changes state at approximately 1/2Vcc then

Delay = 0.7 CR (approximately)

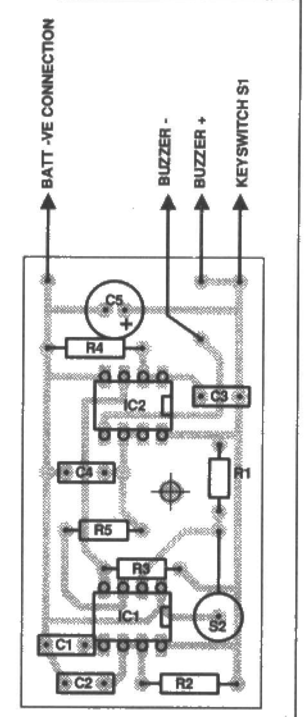


Fig.2: Component Overlay Diagram

Reset (Turn-on) Delay

The length of this delay was not critical, so a +/- 20% tolerance tantalum capacitor was used. Its leakage current will affect the calculated delay length. A 22µF capacitor and 1.8M resistor gave a delay of approximately 21 seconds.

Sounder (Turn-off') Delay

Since this delay is short it needs to be calculated more accurately, so a polyester capacitor was used because of its +/-5% tolerance and low leakage. A combination of 1µF capacitor and 8M2 resistor gave a 7 second delay. The PCB can accept a tantalum capacitor if a much longer delay is required.

As there may be some variation in the threshold voltage between different 40107BE ICs, several values of R5 may need to be tried. However, I got the same delays from two different 40107BE ICs.

Construction

Fit the components as shown in the component overlay diagram, Figure 2. Both ICs are fitted in sockets. IC2 is static sensitive so the usual handling precautions apply.

Vibration detector S2 is supplied with a single thick pin which is fitted to the PCB pad as shown. Its other connection is made by soldering a link between the PCB pad and S2's case. The case layout is shown in the accompanying photograph. The PCB is mounted on a 1/4in M3 spacer. The sounder is also attached using M3 mounting bolts. A grill is made as shown in the photograph and the key switch is mounted in a 19.9mm diameter hole drilled in the case. The PP3 battery holder is attached using Quickstick pads.

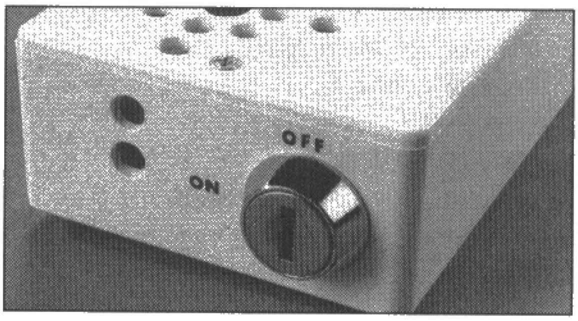
Testing

First fit the battery and test that the unit's quiescent current is approximately 135µA. An initial slow surge to several mA (due to 40107BE Reset buffer's slowly changing inputs) will occur before slowly falling to a steady 135µA. If all is well the operation of the alarm can now be tested.

Turn the key to switch the alarm circuit on and shake the alarm until the sounder is operated. The time between switch-on and sounding is the Reset (turn-on) delay (21 seconds) followed by the sounder (turn-off) delay (7 seconds). The sounder should now operate for ((1.1R2C2 seconds - (turn-off delay)) = 25 seconds.

The sounder (turn-off) delay can be calculated by switching the alarm on, waiting for the Reset (turn-on) delay to elapse, then triggering the alarm by knocking it and measuring the delay before the sounder operates.

The alarm should use approximately 15mA when the sounder is operated.



PARTS LIST

SEMICONDUCTORS

IC1	TS555CN
IC2	HCF40107BE

RESISTORS

R1	100K
R2	1M2
R3	100K
R4	1M8
R5	8M2 (may need to be increased/decreased)

All 1% metal film.

CAPACITORS

C1	10nF Ceramic (5mm lead pitch)
C2	22µF Tantalum
C3	22µF Tantalum
C4	1µF Polyester layer
C5	22µF 25V Electrolytic

MISCELLANEOUS

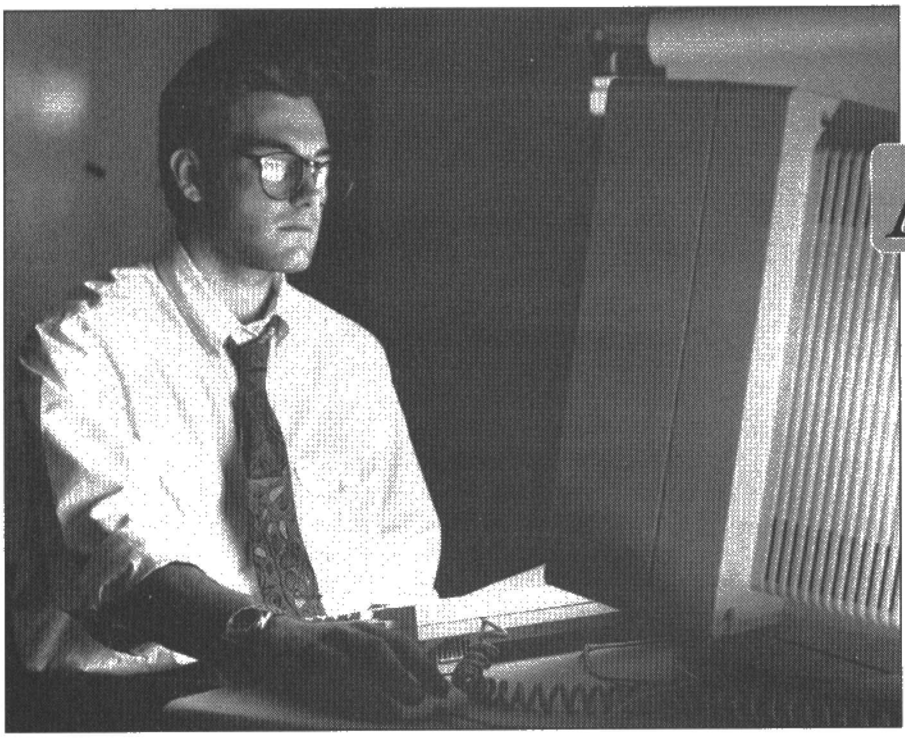
WD1	Maplin High Power Buzzer (FK84F)
S1	Keyswitch
S2	Maplin Vibration Detector (UK57M)

Maplin Box PB1 (114 x 72 x 38 mm)
Maplin Recess Plate (HH23A)
Alkaline PP3 battery
PP3 Clip
Maplin PP3 battery holder (CK65V)
Two 8 pin DIL IC sockets
PCB pins
Quickstick pads
Connecting wire
Three 16mm M3 bolts
Three M3 nuts
One 1/4in M3 spacer

BUYLINES

All the components for this project are available from Maplin Electronics Ltd.

PCB Design Programs



Alan Chadwick looks at some PCB design programs for the hobbyist

As a keen electronics enthusiast I enjoy designing and bread-boarding new circuits, but find the task of producing suitable PCB layouts rather tedious. For many years I have made do with nothing more sophisticated than 0.1in graph paper and a pencil and rubber. PCB design programs have been around for some time but in my case have remained a pipe-dream, due to the lack of a suitable computer and the necessary cash.

However, I recently splashed out on a second-hand PC-XT clone, which meant that a PCB design program became a real possibility, particularly as software prices have been gradually falling over the years. Since my experience of

Easy PC

Easy-PC was one of the first so-called affordable PCB design programs to be marketed and this is very evident when it is compared with more modern programs of similar cost. Although it is capable of performing all the basic functions outlined in the introductory section, it has a number of awkward characteristics and lacks the polish of other programs.

The screen has three small squares across the top which provide access to the pull-down menus and a short status line at the bottom. A number of the menu options lead to very confusing text screens for setting such things as track and pad sizes.

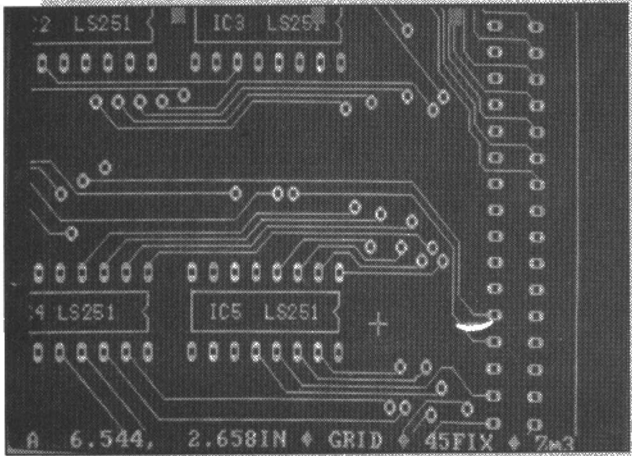
Only three colours are available for assigning to a possible ten layers even in EGA mode. The colour selected for the silk-screen layers is also used for objects which occur on all layers, which can be confusing.

Symbols are selected from the library by means of a code. You can display the contents of the library but this is simply a list of codes with no descriptions attached and so until the symbol is on the PCB you don't know whether it is what you want.

There is very little status information displayed on the screen despite the space available in EGA mode. Pad and track sizes are selected by a code number which corresponds to a size set on a separate text screen. An indication in the status line of the actual pad and track sizes would be useful.

There is only a subtle change in the appearance of objects when they have been selected. This makes editing rather tricky, particularly in the case of tracks as it is difficult to see which segment is going to be affected when a node is deleted.

On the positive side the redraw speed is very good and a large area



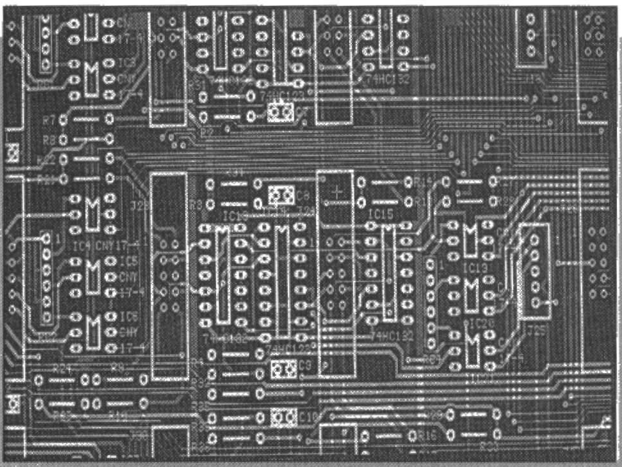
```
A  6.544,  2.658IN ♦ GRID ♦ 45FIX ♦ Zm3
```

Boardmaker 1

Boardmaker 1 follows very similar lines to Easy-PC but with most of the deficiencies mentioned previously removed. It makes good use of the larger EGA colour palette with a choice of six colours for various layers and types of object. A seven-label menu bar runs across the top of the screen with plenty of status information in a single line at the bottom. The text screens are retained, but options are changed via a series of drop-down menus accessible with the mouse.

A list of symbols in the library can easily be called up and selections made directly from it. A graphic preview of the chosen symbol is given before the component is placed on the board, which I found very useful. Editing tracks is far easier with a clearer indication of the segment of track being changed and the proposed modified route. There are also many useful extra facilities. One of these is the ability to automatically increment the number part of a component reference. Another highlights the full length of a selected track, which makes checking connections very simple. Ground planes can be quickly produced with a block fill function.

At £95 Boardmaker 1 is very good value.



Supplier: Tsien (UK) Ltd,
Cambridge Research Laboratories,
181A Huntingdon Road,
Cambridge, CB3 0DJ.
Tel: 0223 277777
Hardware requirements: IBM PC or compatible, 640k RAM, two floppy disk drives or one hard and one floppy, DOS 3.0 or later, Hercules, CGA, EGA, VGA graphics.
Price (excluding VAT and p&p): £95
Upgrade? Yes

computer technology stemmed from the days of the ZX81 it took me a little while to come to terms with DOS, disk drives and databases, but as soon as I felt that I was 'up to speed' I decided to have a look at what was on the market.

Spoilt for Choice

It immediately became obvious there was a wide range of software available but limiting my budget to around £100 soon narrowed the field down to the so-called entry-level programs.

of the screen is available for PCB display.

A timer is incorporated that periodically bleeps and asks you if you want to back up your work so far. This is useful if you are in the habit of falling asleep at the keyboard!

Although the price of Easy PC has fallen from £275 when originally released to £98, it is still outperformed by some cheaper alternatives.

Supplier: Number One Systems Ltd, Harding Way, St Ives, Huntingdon, Cambridgeshire, PE17 4WR.
Tel: 0480 61778
Hardware requirements: IBM PC or compatible, 512k RAM, Hercules, CGA, EGA, VGA graphics. Mouse recommended.
Price (excluding VAT and p&p): £98
Upgrade? Yes

The main feature I was looking for in a program was the ability to easily edit the PCB layout to achieve a high density and the minimum of links, something that is very time consuming with paper and pencil. Of secondary importance was a schematic drawing facility, although many PCB design programs include this at no extra cost. Similarly, I was not particularly interested in anything more than single-sided boards, although most programs seemed to handle up to eight.

Autorouting of PCB tracks looked like a nice idea at first but it soon became apparent that autorouters were not usually available at the budget end of the market and in any case were often intended for double-sided boards.

I discovered that my choice of program might also be restricted by hardware requirements. Although many low-cost programs will run on a basic PC with possibly only a CGA or monochrome display, the trend in minimum requirements is towards EGA graphics, a mouse and a hard disk. In the end I decided to upgrade my PC from CGA to EGA graphics and install a hard disk drive and I was very satisfied with the benefits.

Evaluation

Taking account of all the above considerations, the choice was now between the handful of programs. Most of these have been reviewed individually elsewhere, but without a basic knowledge of PCB design programs the articles were not easy to follow and the fact that the reviews were written by different people made comparisons difficult. I decided that the only answer was to obtain the demonstration disks which are available for most of the programs and make my own comparison. I hope this article will save readers the trouble of doing the same.

Not surprisingly, I found a similar range of functions included in all the programs and the description of these should serve as a good introduction for those readers unfamiliar with PCB design programs. In the section on each program I have only commented on the method of implementation of the standard functions and highlighted any differences in the facilities available.

Many of the programs I looked at are entry-level versions of more comprehensive packages, which would be worth investigating if your budget can stand it. Alternatively if you think you will have spare cash in the future, check whether the basic program can be easily upgraded.

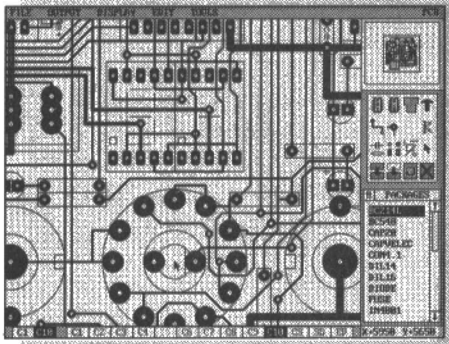
The system requirements for each program are shown in Table 1. All testing was done on an Amstrad 1640 with EGA graphics, Amstrad mouse, 20 Mb hard disk, and an Epson FX-85 9-pin dot-matrix printer.

The Results

With all the programs, I found I spent a lot of time zooming and panning in order to view the right area of the board in

PCB II

PCB II again provides a set of functions very similar to the previous two programs but with a far more modern graphical user interface which in many respects is very similar to a GEM environment. There is still a pull-down menu bar across the top of the screen but most of the common functions are selected by pointing and clicking on icons in a tool-box area to the right of the screen. The contents of the tool-box changes depending on the mode of the program.



At the bottom right of the screen is a small GEM-type selector window which is used for selecting different types of track, pads and components. At the top right is an overview window which permanently displays a miniature view of the layout. By pointing and clicking in this overview area any part of the layout can be displayed on the main screen. Along the bottom of the screen is the layer selector, used to select which board layers are displayed. Only two copper layers are allowed with PCB II.

Placing components on the layout is a two stage process. First of all the components that will be required for the particular circuit are selected from the main library and placed in the selector window at the bottom right of the screen. Each type of component is then selected from this window and placed in position on the board. I found this a very efficient method of working, as on a small layout you may only need half a dozen component types out of a library of several hundred.

Pads and tracks are placed in a similar way, although, as there is a far more limited range of styles. these are immediately available in the selector box without being called up from a library. Text is available in various heights and widths but the thickness is fixed.

The program is very much oriented towards use of a mouse. Once you get the hang of it this is a very speedy method of working but it can be frustrating at first. For instance, once the type of component has been selected each press of the left-hand mouse button lays down another component. This is unnerving when you have been used to selecting the component with the first press, moving it into position and then fixing it with a second press as in the Easy-PC and Boardmaker programs.

Most objects are easily selected by pointing anywhere within their outline and pressing the right mouse button. However a second press of the button immediately deletes the object with no request for confirmation. Sensibly, there is an undelete function.

The track editing function is very powerful allowing sections of track to be modified or deleted at will. The sections do not even have to begin or end on existing nodes. Selecting tracks is no problem if they have been routed with the grid snap option on. If not, any vertical or horizontal track can only be selected by pointing precisely at its centre-line which can be very difficult to find.

Dialogue boxes, another GEM concept, are used for editing such things as text and pad sizes. These consist of an outline containing options that can be selected with the mouse and text fields for keyboard input.

As with Boardmaker 1 there is an auto-increment function for component references, a net highlighter and a block-fill facility. Although PCB II is limited to PCB design, a schematic drawing program called Isis Supersketch, employing a very similar user interface, is now bundled with PCB II, the complete package being known as Cadpak.

At £79 I thought this was an excellent buy.

Supplier: Labcenter Electronics,
14 Marriner's Drive,
Bradford, BD9 4JT.
Tel: 0274 542868

Hardware requirements: IBM PC or compatible, 640k RAM, DOS 3.3 or later, Hercules, CGA, EGA, VGA graphics, hard disk, mouse.

Price (excluding VAT and p&p): £79

Upgrade? Yes

Quickroute 1.5

Quickroute is a shareware PCB design program of very moderate cost. The initial screen layout looks promising with a menu bar across the top of the screen, a row of icons called a button bar immediately below and status information and co-ordinates along the bottom. In fact the selection of the various functions using the menus and icons is fairly logical, if cumbersome at times, and helpful prompts appear at each stage. There is also an on-line help facility which, although common elsewhere, seems to be rare in PCB design programs. Most of the usual facilities are available, but for me there are a number of minor irritations and major flaws in the program.

The redraw time is very slow especially if the grid is enabled. A sample layout supplied with the program took 10 seconds to redraw although admittedly this was a fairly large double-sided design. There is a 'turbo' option, which speeds things up a bit by only drawing the outline of objects but the clarity of the display suffers. A quick zoom option has also been introduced in recent versions, presumably in an attempt to solve this problem.

Panning is achieved by pressing the right mouse button and a handy custom zoom level can be set so that the design just fills the display area. However there is no auto-pan which would be very useful if you wanted to route a track beyond the display area boundary.

Placing of components is frustrating as the first click of the mouse fixes them in position with no opportunity for adjustment. Editing of individual objects is limited to pads and tracks. With the pick mode selected, pointing and clicking causes the nearest pad or track to be marked with a cross. Options then allow it to be deleted, moved or copied. Each segment of a track is treated as a separate object. Similarly, components from the library are

Ranger 1

Ranger 1 is a complete CAD package, although at £100 without the autorouter it is still competitive with many PCB design programs. When using the graphic editor to design a schematic or PCB layout there is a row of menu boxes along the bottom and left-hand side of the screen. To select a menu box the cursor is positioned in the box and the mouse button pressed. This selects the function or changes the contents of the menu boxes to another set of options. There are no short-cut keys. The remainder of the functions are selected through a messy and inconsistent assortment of text screens using function keys, cursor keys and the mouse. However, prompts are provided.

The cursor moves in a series of small jerks which do not correspond with the grid points, even when the grid snap facility is on. This makes it difficult to consistently select or place objects except by using a high zoom level.

To use the package for simple PCB design, components must be selected by code and a netlist produced manually by entering a list of connections. This is a very tedious business and it is far better to use the package as intended and produce a schematic diagram from which the program will automatically generate a component list and a net list.

Whichever route is chosen the next step is to use the graphic editor to place the components on the PCB. Connections can be shown as a 'rats nest' whilst positioning the components, which is very helpful when trying to minimise track complexity.

If you can afford the extra £50 the tracks can now be autorouted. Otherwise, manual routing involves selecting a connection from the rat's nest and converting it into a properly routed track by adding and moving bends to 'rubber-band' the track into the desired position. The manual routing facilities are really intended for tidying up a previously autorouted board and are nowhere near as easy to use as those in a purely manual PCB design program.

As a CAD package, Ranger 1 seems to be very comprehensive. For hobby use, the complexity and poor user interface make it a poor choice.

A version of Ranger 2, Ranger 1's big brother, has recently been released as shareware. This has all the features of the full package but is restricted to 32 parts or 128 component pins.

Supplier: Seetrax CAE, Hinton Daubnay House, Broadway Lane, Lovedean, Hants, PO8 0SG.
Tel: 0705 591037

Hardware requirements: IBM PC or compatible, 640k RAM, DOS 2.0 or later, EGA, VGA graphics, 20M hard disk. Mouse recommended.

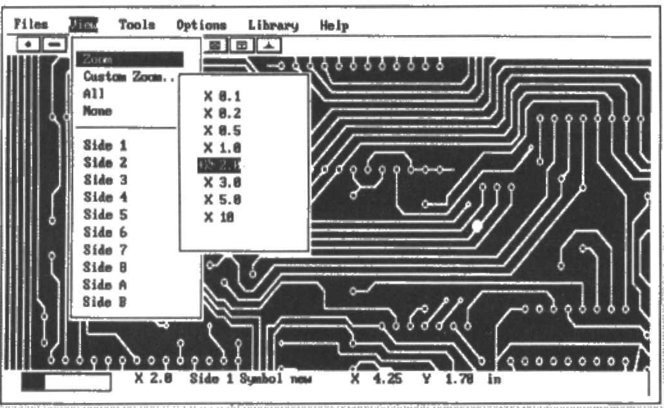
Price (excluding VAT and p&p): £100

Upgrade? Yes

sufficient detail, something that you do automatically when using pencil and paper. It is therefore important that these functions are easy to use and the redraw time is not too long.

Of course, none of the programs solve the problem of producing the board itself, even though they ease the design of the layout. Reasonable quality artwork can be obtained using a dot-matrix printer, particularly if printed at twice full size with a new ribbon, but this then needs to be reduced to a full size transparency. Various methods were discussed in ETI (Read/Write September 1991 to January 1992) including photocopying on to film or spraying a paper copy of the layout with transparentiser. More recently (Read/Write May 1993) a reader suggested using carbon paper and draughting film in a dot-matrix printer.

If you can afford it, there are plenty of companies willing to produce either film positives or even complete boards directly from information supplied on disk in an acceptable format.



treated as individual parts once they have been laid down and so can only be moved as a whole by using the block functions.

The block functions are selected from the button bar. Once the block has been defined by pointing at diagonally opposite corners the rectangular outline is immediately attached to the cursor. However, instead of the outline remaining in position and the cursor jumping to its centre, it is the outline that is redrawn round the cursor so that the relationship of objects to the block outline is lost. As the block contents are not continuously redrawn while the outline is moved, it is very difficult to place the block in its new position. Furthermore, any tracks crossing the block boundaries are not 'rubber-banded' to the new position.

On the positive side, there is a simple autorouter included but its performance is disappointing, leaving you to finish off connecting most of the tracks. Output options are limited to 9 and 24-pin dot matrix, laserjet printers and HPGL plotters but this is adequate for hobby use.

Quickroute does provide a working program at a very competitive price but personally I would rather pay twice as much and avoid the frustration of coping with Quickroute's limitations.

Supplier: Powerware, 14 Ley Lane, Marple Bridge, Stockport, SK6 5DD. Tel: 061 4497101

Hardware requirements: IBM PC or compatible, 512k RAM, Hercules, CGA(mono only), EGA, VGA graphics, mouse.

Price (inclusive): £39

Upgrade? No

Layo1

Layo1 is a recent addition to the market originally written as an 'in-house' PCB design program for a Dutch electronics company. Later, a facility for schematic capture from Orcad or similar packages was incorporated. However, the versatility of the program means that suitable component and netlists can be created manually although they are by no means essential to allow the program to be used successfully.

The lowest priced version has all design facilities but is restricted to 4000 datalines. This should cope with typical hobby-sized circuits as long as you don't use too much text which seems to eat up datalines.

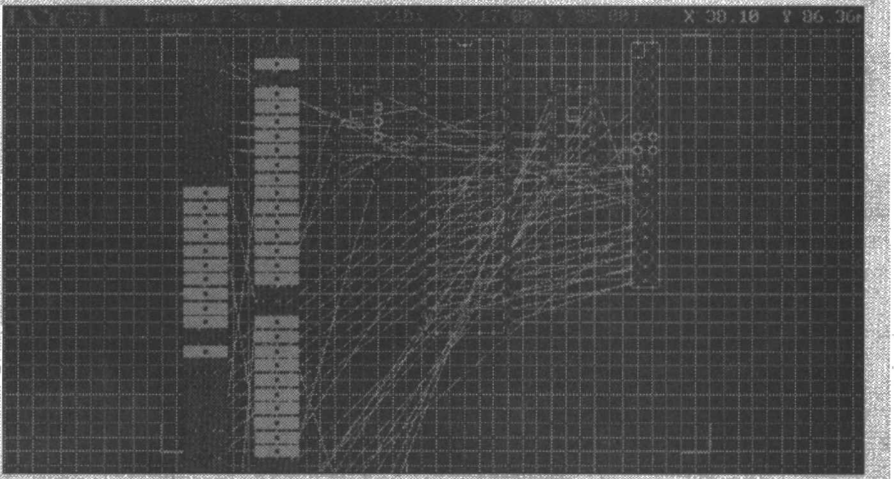
The package comes with a project manager to provide a user-programmable menu system, initially set up to allow selection of the graphics editor program for PCB design, a text editor, a font editor, or an output driver program. Design files are grouped under a project title and each user of the program can have his own set of preferences.

The display area is uncluttered, with a single status line across the top and an optional overview window in the top left-hand corner. However the menu structure leaves a lot to be desired. The main menu bar is called up by pressing return on the keyboard or the right-hand mouse button. This is confusing as the right-hand button is elsewhere equivalent to the Esc key which is used to exit from menus and functions. Functions are selected from the menu bar by pressing return or the left-hand mouse button. However, not all functions are available by this method and must be selected instead by various keyboard characters. There are also short-cut key combinations for the main menu functions. To further complicate things, functions can be activated by pressing combinations of the three mouse buttons, the effect of which vary depending on the current mode. The possible combinations and their effects can be discovered by pressing F1.

On the positive side, the program remembers the last path selected through the menu options. There is also a macro facility so that single keys can be programmed to activate frequently used keyboard sequences. Selecting a zoom level is slow but a useful option magnifies the board to fill the screen.

Designing a PCB involves three basic stages. Layo1 is very versatile as it allows a number of alternative methods to be used for each stage. The first stage is to select the components, which can be done manually from the library in the usual way but is rather a tedious process as the component libraries are at the ends of the branches of a large directory tree which has to be stepped through each time a new component is required.

Importing a component list from a schematic program, or writing your own by means of Layo1's text editor, avoids this problem as the components will be automatically called up and positioned. A print out of all the library components is included in the manual.



The next stage is to define the routes. This is optional if you intend to lay down the tracks manually but to use the autorouting or rats nest facilities a netlist is required. This can be imported, written using the text editor or produced 'on the fly' by simply pointing at pads that are to be connected together. The resulting connections can be displayed as a 'rats nest' which then allows manual repositioning of components to minimise track complexity.

Moving components is not as elegant as with some programs. If the display is continually updated as the component is moved, the redraw time is fairly slow especially if tracks are connected. To get round this problem the user has the options of redrawing when a mouse button is pressed, or after a set delay once the cursor has stopped moving.

A nice facility is the ability to rotate a component by pressing both mouse buttons at once.

At the final stage of routing the tracks, Layo1 is even more flexible. The most basic method is to route by hand, defining where each bend is to occur. Any of the other methods requires a netlist and uses the autorouting function in various ways. Before invoking the autorouter, certain parameters have to be set such as whether the board is double or single sided, whether vias are allowed and what type of routing strategy to use. Once this has been done, the auto router can be unleashed either on the whole board or on various restricted parts such as a selected net or a selected trace.

If the autorouter has not been 100% successful, the unrouted nets can be displayed. These can be manually routed or the program can be asked to reroute certain tracks and nets which will often allow completion of the remainder.

Draft quality output, which is supposed to be satisfactory for prototypes, can be obtained from within the graphics editor. The full range of output is available by using the separate output driver program.

Supplier: Pentagram Electronic Designs, 6 Pasture Close, Clayton, Bradford, West Yorkshire, BD14 6LY. Tel: 0274 882609

Hardware requirements: IBM PC or compatible, 640k RAM, DOS 3.0 or later, EGA, VGA graphics, hard disk, mouse preferably three button.

Price (excluding VAT and p&p): £99 for 4000 data lines

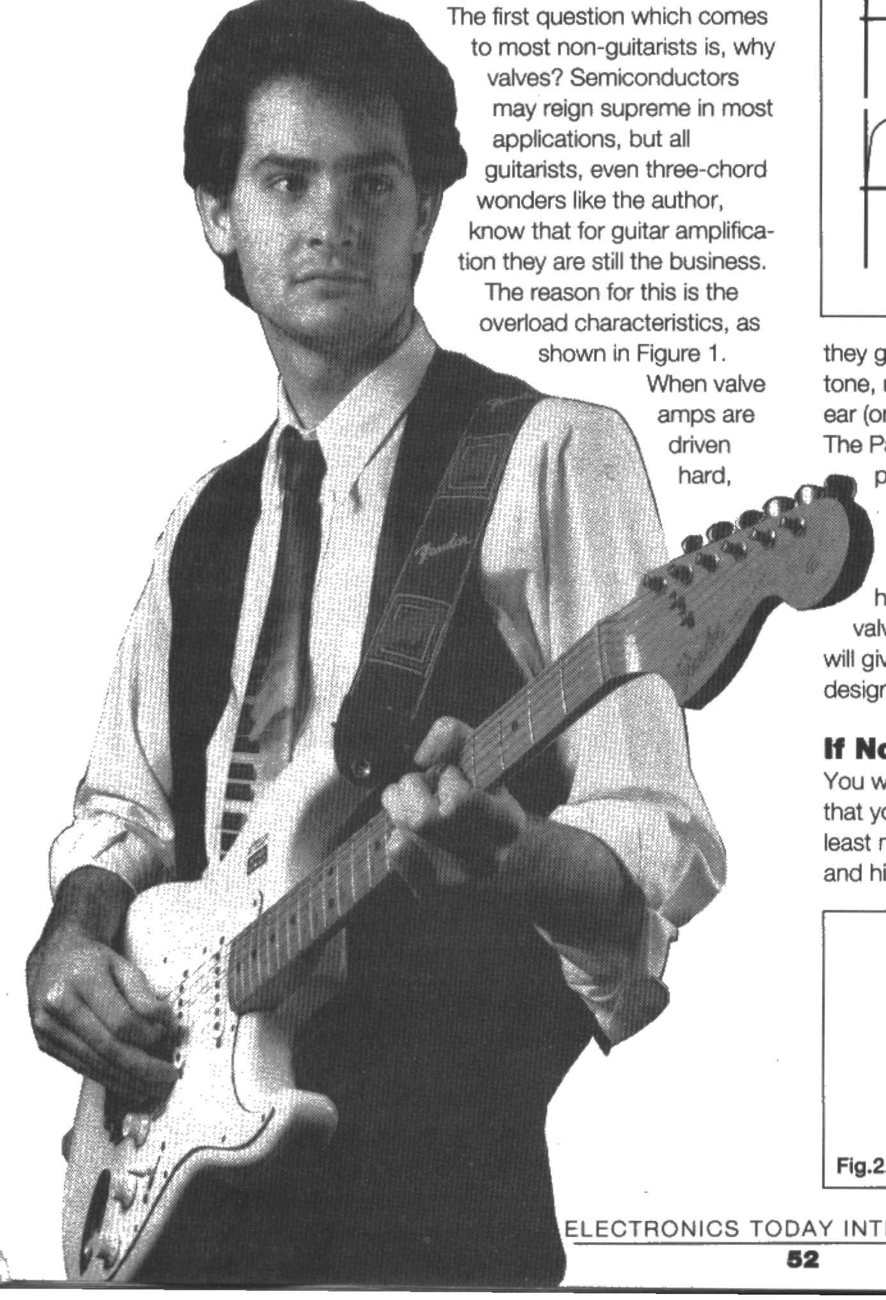
Upgrade? Yes, but same facilities

Paleface Minor guitar amp

Part 1

Rediscover the unique sound of valves with this amplifier project from Dave Bradshaw

Welcome to the world of valves. In this short series, I am going to describe two guitar amplifiers - the first is a 15W design, intended as a practice amplifier, the second a 50W version, with some extra facilities, that is powerful enough to 'gig' with. Firstly, however, I want to describe some valve basics and I'm including some circuits which you can experiment with using a prototyping board.



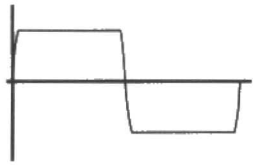


Fig.1a. On overload, semiconductor amplifiers tend to square off the output signal, as shown for a purely resistive load.

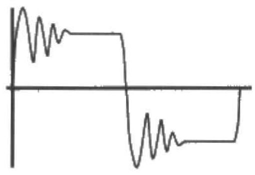


Fig.1b. With a reactive load such as a typical loudspeaker, there can be quite a lot of ringing at the switch off points and the circuit can act like a class D oscillator, injecting a lot of destructive energy into the loudspeaker.

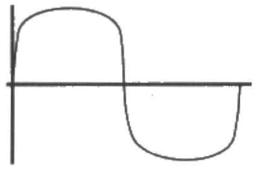


Fig.1c. Valve output stages don't have such a sharp cut-off, so ringing is rare and the overall effect is less destructive and much more pleasing.

Why Valves?

The first question which comes to most non-guitarists is, why valves? Semiconductors may reign supreme in most applications, but all guitarists, even three-chord wonders like the author, know that for guitar amplification they are still the business. The reason for this is the overload characteristics, as shown in Figure 1. When valve amps are driven hard, they go into overdrive gracefully, producing a pleasing mellow tone, rather than the harsh solid-state noise that assaults the ear (or even worse, speaker-destroying high frequency ringing). The Paleface allows you to overload either the preamp or the power amp, which produce different characteristics.

With varying degrees of success, designers have sought to simulate the distortion of overloaded valves using solid state circuitry. But why simulate when you can have the real thing? There are also some who believe that valve hi-fi amplifiers are the bee's knees. I hope ETI readers will give me the chance to investigate this by building a practical design sometime in the not too distant future.

If Noise Annoys

You will not get the noiseless performance from a valve amp that you routinely expect from a semiconductor amplifier, at least not this side of several thousand pounds. Both mains hum and high frequency noise (HF noise, or hiss) are inferior with the

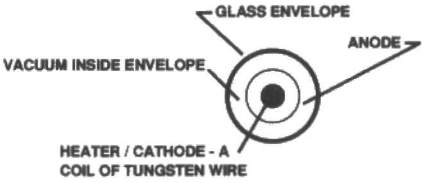


Fig.2. Cross-section of a diode.

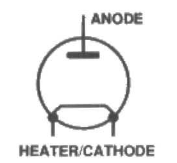


Fig.3. The symbol for a single valve diode

valve amp.

Supply line ripple is the main culprit in the hum problem. This is due to the poor availability and high cost of high-voltage electrolytics. The lower charge stored in the capacitors means there is a disproportionately higher ripple voltage on the high voltage supply line.

For example, the largest easily available 400V capacitor is 4705 and this currently costs nearly £10, one-off. At maximum voltage, this stores 188 millicoulombs of charge. By comparison, a commonplace 10,0005 25V capacitor can store 250 millicoulombs for around £1.50 to £3.50, depending on ripple current capability.

The other contributor to hum performance is the high signal impedances in valve circuits. This is a problem at the input stage, where signal voltages are low. However, intermediate signals tend to be several volts, so the noise they pick up is much less significant. There are lots of sources of hum in the amplifier itself, for example in the power supply and the 6.3V AC for the heaters and the high voltage secondaries on the power transformer.

A contributing factor is that overall feedback is rarely used in preamplifier stages, and in power amplifiers the level of feedback is relatively low. However, care with layout and some judicious use of screening can diminish the hum.

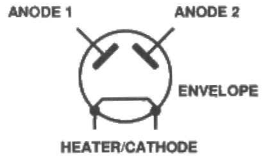


Fig.4. The symbol of a dual diode

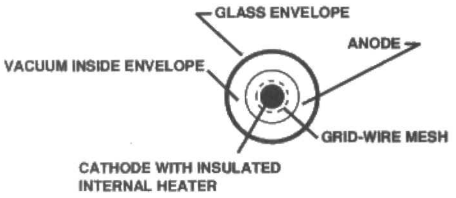


Fig.5 Cross-section of a single triode valve.

As far as high frequency noise (hiss) is concerned, valves are not as good as semiconductors, because they operate at high temperatures, so they heat up all the surrounding components and they use high voltages. Again, the generally higher signal voltages offset this to a large measure.

Valve Basics

I'd like to be able to recommend a good book on valves, but have been unable to find any that are in print - all mine are 30 year old! So here goes...

Valves have three types of electrode, sealed together in a high vacuum using a glass envelope. The cathode is a cylindrical pipe made of special metal at the centre. The anode is a cylinder of metal around the cathode. Between these are grids which are also cylinders, but this time of mesh. Valves typically have one or three grids. However, the very simplest valve has no grid at all, just a cathode and an anode.

Cathode Action

When it is red hot, the cathode emits electrons which form a small cloud around it. This phenomenon is called thermionic emission. When first switched on, the cathode takes a little while to get hot enough for electrons to be emitted, hence the typical warm-up time of valves.

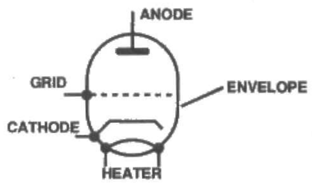


Fig.6. The circuit symbol for the triode valve. Note that the heater is often left out for simplicity, although the valve cannot function without it.

As readers will know, electrons can move around freely inside metals. How quickly the fastest move depends on the temperature of the metal. When the metal is heated to a high enough temperature (say, 1000∞C), some electrons will be moving fast enough to escape altogether from the surface of the metal. This is rather like water molecules evaporating from the surface of a pool of water. Some materials emit electrons very easily, particularly certain oxides, so it is normal to coat the cathode with one or more different such oxides.

To make the cathode hot enough, it needs a heater, i.e. a thin tungsten wire which is made very hot by a current passing through it. The simplest arrangement is to make the heater and cathode the same thing. This type of valve is said to be directly heated. However, this severely constrains the usefulness of the circuit, because we either have to connect all the cathodes together (imagine designing transistor circuitry if all the emitters had to be connected together), or each valve would need a separate heater supply.

Most valves are indirectly heated. The heater is a winding of tungsten inside the cathode but insulated from it by a thin layer of aluminium oxide. The heater plays no other part in the circuit unless the insulation breaks down. Nearly all heaters require 6.3V (usually AC supplied from a special transformer winding). The current they consume depends on valve type.

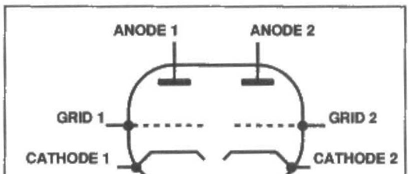


Fig.7. The circuit symbol for a dual triode. The envelopes are sometimes completely joined, but mostly they are separate. The heaters are not usually shown.

Diodes

The very simplest valves have no grids and are diodes (Figure 10). When the anode is positive with respect to the cathode, electrons are attracted to it and are absorbed into it, i.e. a current flows through the vacuum. If the anode is negative with respect to the cathode, no current can flow, as the anode is not hot and does not emit electrons. This is the rectifying action that characterises a diode, discovered in 1883 by Edison. Figure 2 shows the lay-out of a valve diode and Figure 3 shows the symbol of a valve diode.

As with semiconductor diodes, there are two main types - signal diodes, with low current capability but also low capacitance and rectifier diodes, with high current capability. Both types have been completely replaced by semiconductors in all but the most esoteric of applications. However, you may well come across valve rectifiers in older valve amplifiers.

Because of the high voltages at the cathode, valve rectifiers are normally directly heated. The voltage between the cathode would be so high that some diode action would occur between

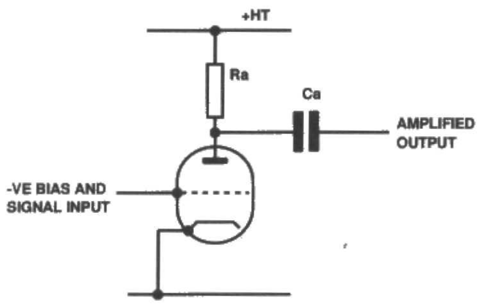


Fig.8. The basics of a triode cathode-coupled amplifier.

the heaters and the cathode. For this reason, they require a separate heater supply insulated from all the other valves.

Most valve rectifiers are dual diodes. Some of these are two anodes with a common heater/cathode, but others have two separate diodes within the same envelope, with the heater/cathode windings joined - the effect is the same. Figure 4 shows the symbol. Dual diodes were the fore-runners of today's bridge rectifiers. For example, with a 250-0-250V transformer, a single rectifier valve produced a full-wave rectified output.

Valve rectifiers have one advantage over semiconductor diodes, in that they start to conduct slowly when first turned on as their heaters warm up. The capacitors are therefore charged up more gently than with semiconductor diodes and there's much less of a surge of current at switch-on.

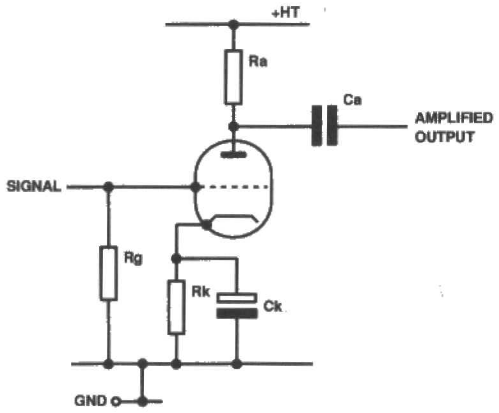


Fig.9. A cathode coupled amplifier that biases itself.

Triodes

Figure 6 shows the simplest type of valve with a grid, a triode valve. A single triode valve is broadly equivalent to a single transistor, although a valve is a voltage-controlled device, so it is closer to a FET rather than a bipolar transistor. Valves have higher gain and linearity than FETs and a single valve stage is often equivalent to an op-amp stage. I must hastily add that valve circuitry is nothing like op-amp circuitry.

Most modern triodes are dual triodes, i.e. two separate triodes in a single envelope. The ECC83 used throughout the project is of this type. One can think of these as the valve equivalent of a dual op-amp. The heaters are nominally separate, but are joined. Usually, we apply the 6.3V heater supply between the join and the two other terminals connected together. Again, like the supply rails in op-amp circuits, the heater connections are normally left off but the valve will not work without them.

The grid between the cathode and anode gives us a way to modulate the flow of current between the cathode and the anode. For the valve to work, the anode has to be positive with respect to the cathode so that electrons are heading from the cathode towards the anode - anode voltages of 100 to 300V are typical in triode circuits. When the grid is positive, it has little effect and the valve continues to act as a diode with current flowing, the grid just tending to act as a rather poor second anode.

When the grid is a few volts negative with respect to the cathode, the grid chokes off part of the electron flow between the cathode and the anode. The more negative the grid is, the less current flows, up to the cut-off voltage (the voltage which stops all current flowing).

With the grid voltage between zero volts and the cut-off voltage, small changes in the grid's voltage can make very big differences to the current passing through the valve. To take advantage of this, we apply a steady negative voltage, called the grid bias voltage and add the signal voltage to this. This voltage sets the operating point of the valve, in the same way that the current flowing into the base can set the operating point of a transistor. Choosing the best grid bias voltage is a bit of a black art, and it is normally recommended in valve data charts.

With the ECC83 triodes used in the Paleface Minor, grid bias voltage of -1.5V with respect to the cathode will give a current of around 1.2mA. Other valve types will give different figures, but typically the grid bias is a few volts and the current through the valve is a few milliamps. As long as the grid remains negative with respect to the cathode, no current flows from it.

The signal voltage applied to the grid voltage creates sympathetic fluctuations in the current between the cathode and anode. To turn this back into a voltage signal, we place a resistor (Ra in Figure 12) between the anode and the positive supply.

An important point to note here is that valve supply voltages are often labelled HT, or HT+ (for high tension). HT voltages are usually 200 to 400V, and sometimes higher. These voltages should always be treated with respect, for obvious reasons.

The anode voltage will vary in sympathy with the current changes, much in the same way as with an emitter-coupled transistor amplifier, and we gain an inverted but large version of the original signal. We need a high-voltage capacitor, Ca, to block off the high standing voltage (typically 200 to 300V) at the anode. A few more details are needed to make this into a practical circuit.

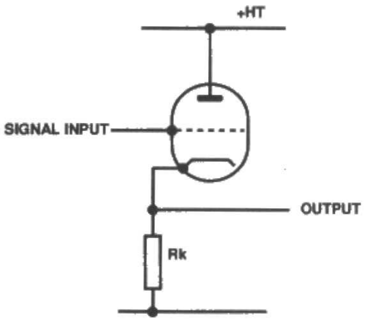


Fig.10. A basic cathode follower.

In most circuits, it is not convenient to have a special negative voltage source to set the operating point. Since this voltage is effectively the signal earth, any noise on it is added to the signal and amplified. There is an easier way to set the operating point and that is to allow the valve to find its own operating point. To do this, we insert a resistor (Rk) between the cathode and ground and add a high-value resistor (Rg) to keep the grid at zero volts, as shown in Figure 9 (ignore the capacitor, Ck, for the moment). This circuit will settle at a point where the voltage is a volt or two negative, so applying its own negative grid bias (because the grid is at zero volts, i.e. negative with respect to the cathode). The amount of current flowing through the valve will depend almost entirely on the size of the cathode resistor. The anode resistor, Ra, makes very little difference to the current flow, provided it is below a certain value.

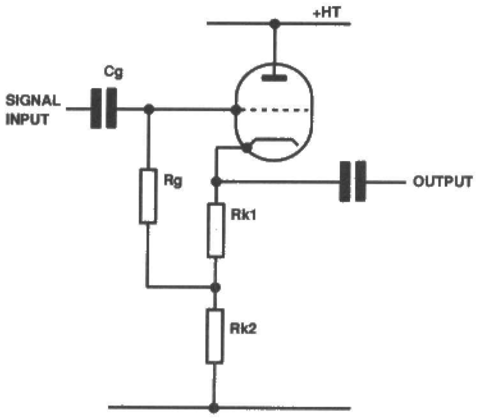


Fig.11. A cathode follower with self-biasing arrangements.

The main disadvantage of using a cathode resistor is that it reduces the gain of the valve by adding local negative feedback. Suppose the signal at the grid temporarily increases the grid voltage. This makes more current pass through the valve, which because of the cathode resistor, increases the cathode voltage in line with the grid voltage. This feedback cancels out most of the current increase caused by the increase of the grid voltage. Similarly, when the grid voltage decreases, the current falls and the cathode voltage falls again cancelling out most of the decrease in the grid voltage. As a result, we get some amplification, but much less than we got with a separate grid bias voltage. This circuit is still useful, because it offers good-quality amplification and a medium gain - typically around 10 to 20 for the values shown.

Adding a cathode capacitor, Ck (shown dotted in Figure 9), stops the cathode voltage responding to AC variations in the current through the valve, and so increases the gain of the stage to the maximum that the valve can give. However, Ck does not affect the DC conditions of the valve.

Another complication is that the valve's gain is quite affected by the current flowing. Calculating the gain in advance requires hours poring over valve characteristic charts, and even then it's only an estimate. It's usually much more fun to try it and see if it works. Then, if you're really serious, you try it with old and new valves and see if it still works.

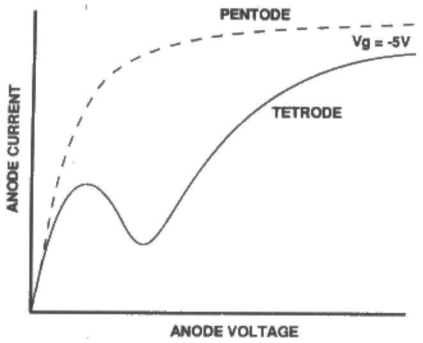


Fig.12. The 'knee' in the response of a tetrode and the correction given by the pentode.

Cathode Follower Circuits

Suppose we ditch the anode resistor and the cathode capacitor (Figure 10). This gives us a cathode follower which is very similar to a bipolar transistor emitter follower, or a FET source follower. Although it has only unity voltage gain, it can provide a lower output impedance. Due to local feedback, the output impedance is considerably lower than the resistance of Rk, which is normally 47 or 100k. For maximum voltage swing, the grid must be biased at around half-way between ground and HT+.

Biasing the grid is a problem. The simplest way is to couple the grid directly to the anode of the previous stage, where there is one. An alternative is to use a voltage divider between earth and HT+, but this requires a capacitor to suppress supply noise, then another resistor to stop the signal being suppressed by the capacitor.

A more elegant way is the self-biasing arrangement in Figure 11. Rk1 is typically 1 to 2k, while Rk2 is 47 or 100k. This works exactly the same way as the cathode-coupled stage biasing. However, both the cathode and the grid are at a high positive voltage and capacitor Cg is needed to block the grid voltage from the input. This circuit has a bonus in that the grid resistor 'bootstraps' the input, raising the input impedance well above the value of the grid resistor Rg.

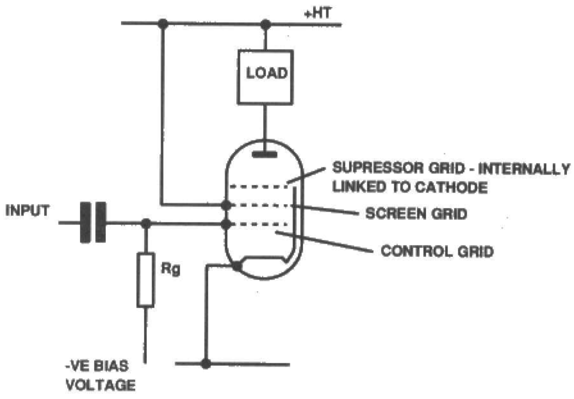


Fig.13. A typical pentode circuit. The load could be an anode resistor with an anode capacitor for a small-signal pentode, or the primary of an output transformer for a power valve.

Triode Limitations

One of the most serious drawbacks of triodes is a result of the small capacitance between the grid and the anode, typically around 10 to 20pF. This stray capacitance gives rise to unwanted negative feedback from the anode to the grid. Small though this feedback is, it can be significant at high gains or at high frequencies. Also, triodes generally do not pass enough current for power amplification.

However, triodes are very useful for low frequencies (typically audio), lower gains (up to around 100) and lower powers (perhaps 100mW). Other, more complex valves extend these limits.

More Complex Valves

In tetrode valves, there is a second grid, called the screen, between the first grid (the control grid) and the anode. Provided it is held at any constant voltage, this minimises the negative feedback from the anode to first grid. Applying a high voltage (usually HT+) to the screen, maximises the current flow through the valve, so increasing the power output. Even though the mesh of the screen grid is kept very thin so that most electrons speed by it and it intercepts very few, a substantial current

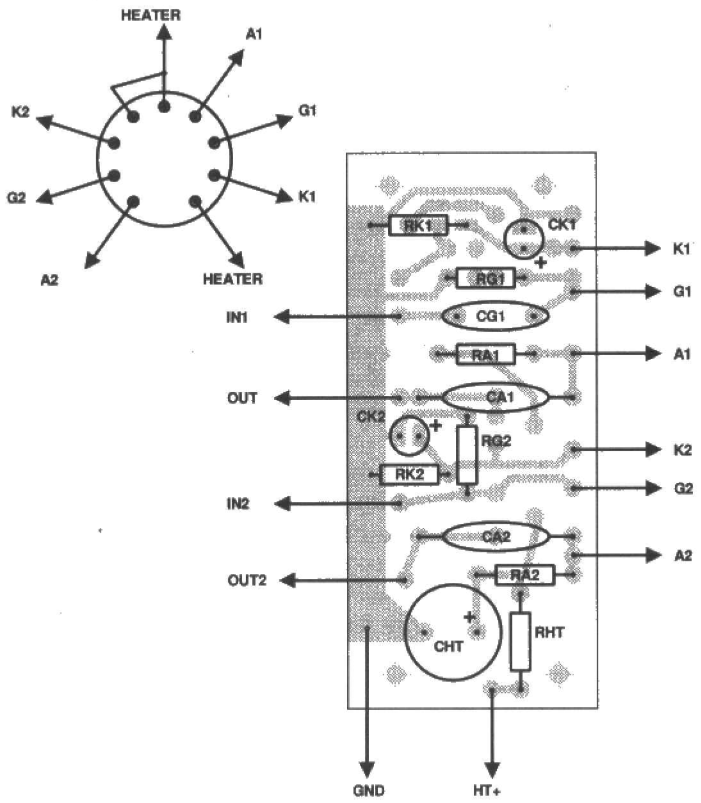


Fig.14. An experimental layout with two cathode-coupled amplifiers, using the prototyping board.

(10mA or more) can flow into the screen grid, as it looks like a rather poor second anode.

However, the tetrode still has a serious problem due to a phenomenon called secondary emission, electrons hitting the anode with enough speed to knock other electrons out of the anode itself. These secondary electrons are attracted to the screen and, when current is flowing through the valve, the screen is often at a higher voltage than the anode. Besides current being wasted by flowing through the screen and not the anode, secondary emission also leads to a 'knee' in the response curve of the valve, which is not good news for linearity.

This problem can be overcome by placing a supressor grid between the screen grid and the anode, thus making the valve a pentode. If this grid is kept at a low voltage (often it is internally attached to the cathode) the emitted electrons do not reach the screen so they return to the anode.

There are two types of pentode, low power and high power. Low power pentodes, such as the EF86, are often used for small-signal amplification, typically as IF amplifiers in valve radios. Two of the most common are the EF80 and the EF86, the latter being designed for audio circuits that demand high gain and low noise.

Besides high power pentodes, constructed as described above, there are also beam tetrodes. In my book these are pentodes, but the supressor grid has become a plate around the anode. Both types are used extensively as audio power output stages, either singly or, more commonly, in push-pull pairs. In Europe, common types are EL34 (capable of 100W from a pair, using an 800V power supply) and the EL84 (also called the 6BQ5, a scaled-down version of the EL34). In the US, common types include the 6L6 (also sold as the KT66 and 5881), and the KT88.

Manufacturer's specs. are actually simpler with more complex valves. Rather like IC specs., they give precise values for the circuit values.

Audio output stages have to use transformers, to match the high output impedance of the valves with the low output impedance of the loudspeaker. Actually, I did once come across a high-impedance loudspeaker driven directly from a valve anode. I couldn't get the radio it was in to work, so I junked it - 25 years on, I know it would now be worth a fortune! Another reason to use transformers is that without a transformer, push-pull operation isn't possible (there are no tubes using holes). I have not drawn a push-pull output stage - you'll see one next month, with a longer explanation of how it works.

Circuits To Experiment With

So that you can experiment yourselves with valves, I have designed a prototyping board to accommodate cathode-coupled and cathode-follower circuits. It makes a neater prototype than the typical rat's nests that infest most valve prototypes. Originally, I planned to mount the valve on the PCB, but this caused too many mounting and access problems and made rather poor use of the board space.

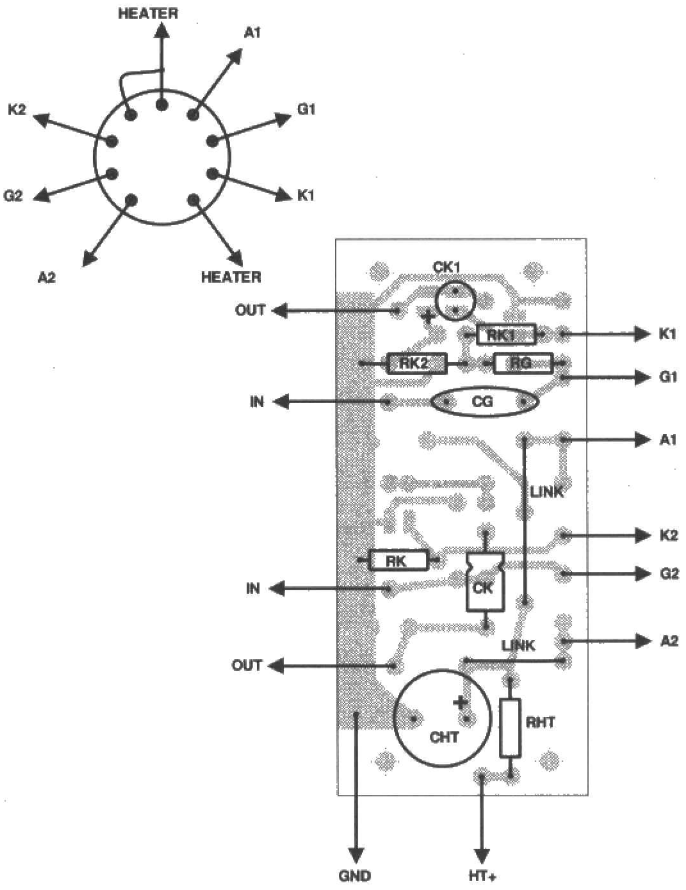


Fig.15. A layout for two cathode followers, the first a self- biasing type.

To build these circuits, you will also need a high-voltage positive supply of 100-300V, capable of giving 10mA and a heater supply of 6.3V, 0.3A. A power supply will be described next month as part of the main amplifier project.

I do recommend beginners at electronics to build some low voltage circuits first, not least because of the high voltages involved. Personally, the first things I built were with valves, but I gave myself a fair number of shocks. Even the experienced should be careful - just 100V is enough to kill, given a sufficiently good contact. Remember also that the smoothing capacitor, Cht, can stay charged after the supply has been disconnected.

The Cathode-Coupled Amplifier

Figure 10 shows the layout for two cathode-coupled amplifier triode circuits, using the prototyping PCB and an ECC83 dual triode valve. There is no necessity to build both if only one is required. The suggested values are given in the table, but these are only suggestions.

A practical use for this circuit is as a valve distortion unit, especially if a low HT voltage of 50-70V is used to give the valves no 'head room'. Rx and Rg2 attenuate the signal between the two stages, to make the clipping more even. These values need some experimentation and Rg2 could be an off-board potentiometer. This circuit will be used in the 50W amplifier.

Cathode Follower

The first stage can be used as a self-biasing cathode follower, using the layout in Figure 11. It is a self-biasing design, the second stage being a simpler stage that needs a bias voltage applied to it. Again, the component values given are just suggestions.

Special Note

This is an advanced project. Not only does it involve working with the mains, but it involves circuits using high voltages. We advise inexperienced readers against building this project as their first electronics project.

PARTS LIST for figure 14

Rg1, Rg2	1M0 Rk1, Rk21k2
Ra1, Ra2	100k 1W
Cg1	100n low-voltage capacitor, or link
Ck1, Ck2	10µ 25V (or leave out)
Ca1, Ca2	100n 400V
Rht	22k
Cht	10µ 400V
Rx	see text

PARTS LIST for figure 15

Rk	47k
Rk1	1k2
Rk2	47k
Rg	1M0
Cg	100n
Ck	10µ 100V electrolytic
Rht	22k
Cht	10µ 400V

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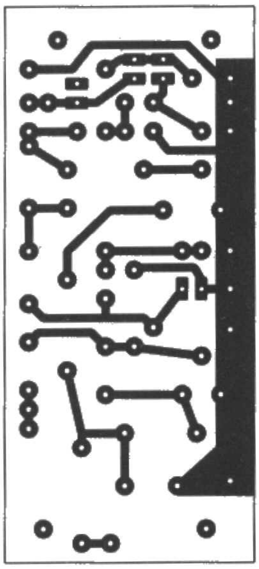
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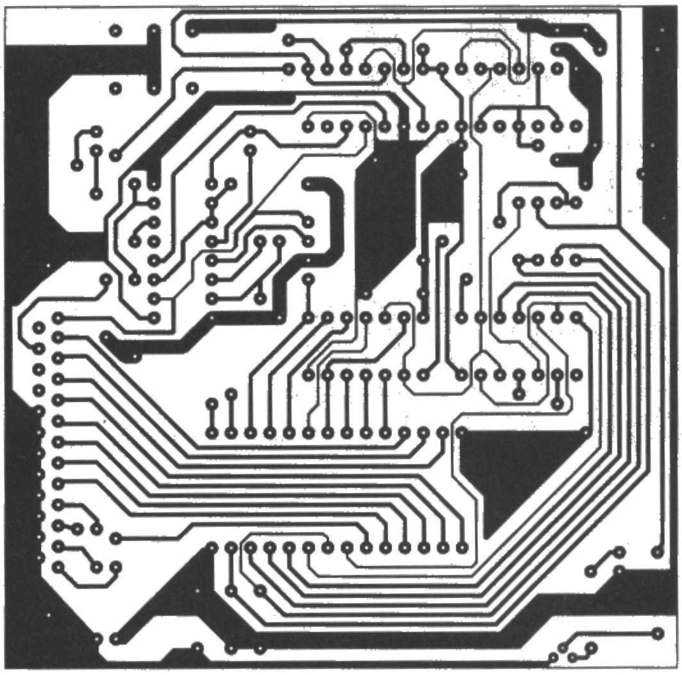
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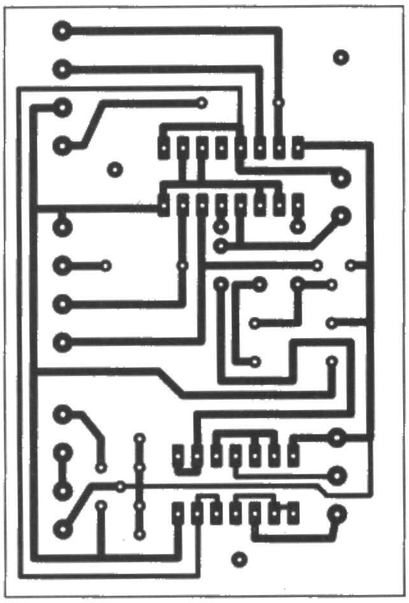
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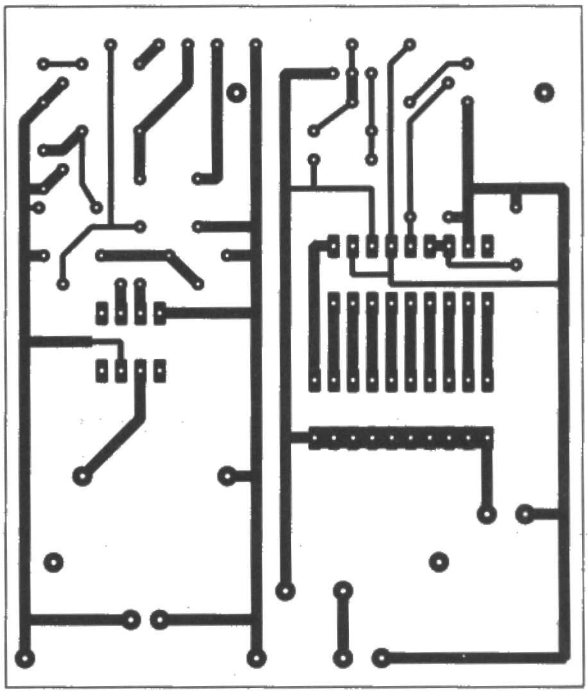
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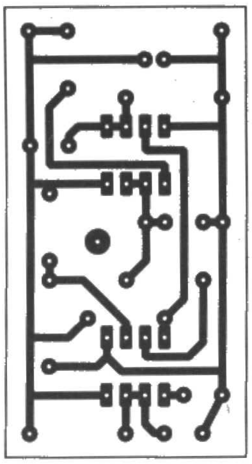
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Open Forum

The electronics industry thrives on innovation. Indeed, without constant development of new products to meet new customer demands, it would probably slowly die. Creating new ideas to meet the demands of new markets is the hallmark of the entrepreneur, and the electronics industry should be the natural home of such people. People who actively look for new markets and new ideas and, in so doing, create new businesses and new jobs. But in the UK, with a few notable exceptions such as Alan Sugar, electronics is not an industry that is brimming over with entrepreneurial activity.

The markets exist for new products, especially in specialist niche areas, and are very often largely unexploited. The talent exists to create the products that would satisfy the demands of these markets, but hardly anyone is putting them together to create new electronics based businesses.

We, seem to be mesmerised by imports from the far east. We seem to have acquired some kind of complex, that people in this country cannot design, make and profitably sell electronics products. To do that you have to have large research budgets and cheap labour - only a big company, a Japanese, Korean, or Taiwanese company, can do that.

This attitude is quite frankly rather simple minded. Anything that can be done by producers in the far east can be done here in the UK. You do not need cheap labour, the savings in import costs more than counter balance this. Neither do you need large R&D budgets, profits can be made from very simple devices.

Look at this issue. The Motor Mate would be bought by a great many motorists at £20, but in small quantities could be made on a kitchen table for just a few pounds. The same goes for the fisherman's bite detector and the bike alarm. Admittedly, none would ever sell in large quantities, but they are potentially profitable products in small niche markets.

So, if the electronics entrepreneur can easily design and make an electronics based product, why are they not getting into the shops?

A Little Learning

Partly, the answer to this is probably a matter of trust. The man in the street is, by and large, completely ignorant about electronics. He cannot tell whether he is making a good buy or throwing his money away. The man in the street relies on a familiar brand name to reassure him that the product is well designed, reliable and value for money. He relies on the fact that it is made in Japan, for that also signals quality and reliability. In other words, the customer is brainwashed by years of advertising, propaganda and his own ignorance.

The other half of the answer is that businessmen find that there is more money to be made, with less trouble, by simply importing products from the far east. All you have to do is sell and take your profit.

So, is there hope? I think there is. We just do not try hard enough, we have lost faith in our own ability to create high quality innovative products at value for money prices. There are probably hundreds of readers of this magazine who have the talent and ability to become electronics entrepreneurs, the founders of a revitalised UK electronics industry.

Come on, lets show the rest of the world what we can do!

Next month ...

In next month's issue of ETI we look at recycling old computers and using them as the basis for some interesting projects. We continue our two series - building a 12W valve guitar amplifier and taking a look at microprocessor interfacing. Projects will include a single board Z-80 computer that can be used as the basis for a wide range of projects. We build a frequency meter adapter, another useful piece of equipment for the test bench. For computer users, there is a printer switch that will allow the user to easily switch between two different printers. We will also be showing how to build a novel text display system that works on the eye's latent image.

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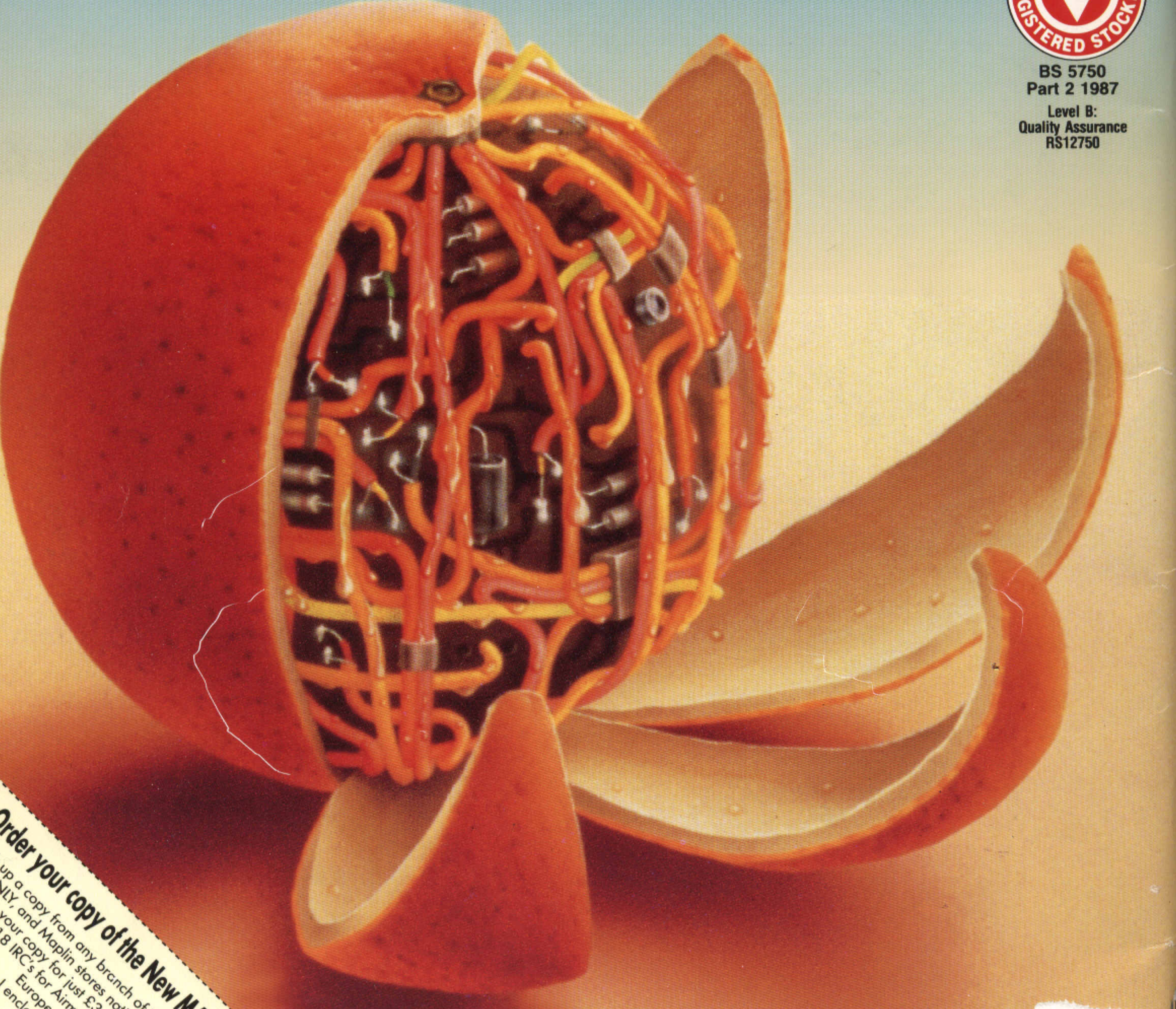

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